

**INSTRUCTION MANUAL
FOR THE
FM-AM SIGNAL GENERATOR
TYPE 202H**



BOONTON RADIO COMPANY
Green Pond Road Rockaway, New Jersey
U. S. A.

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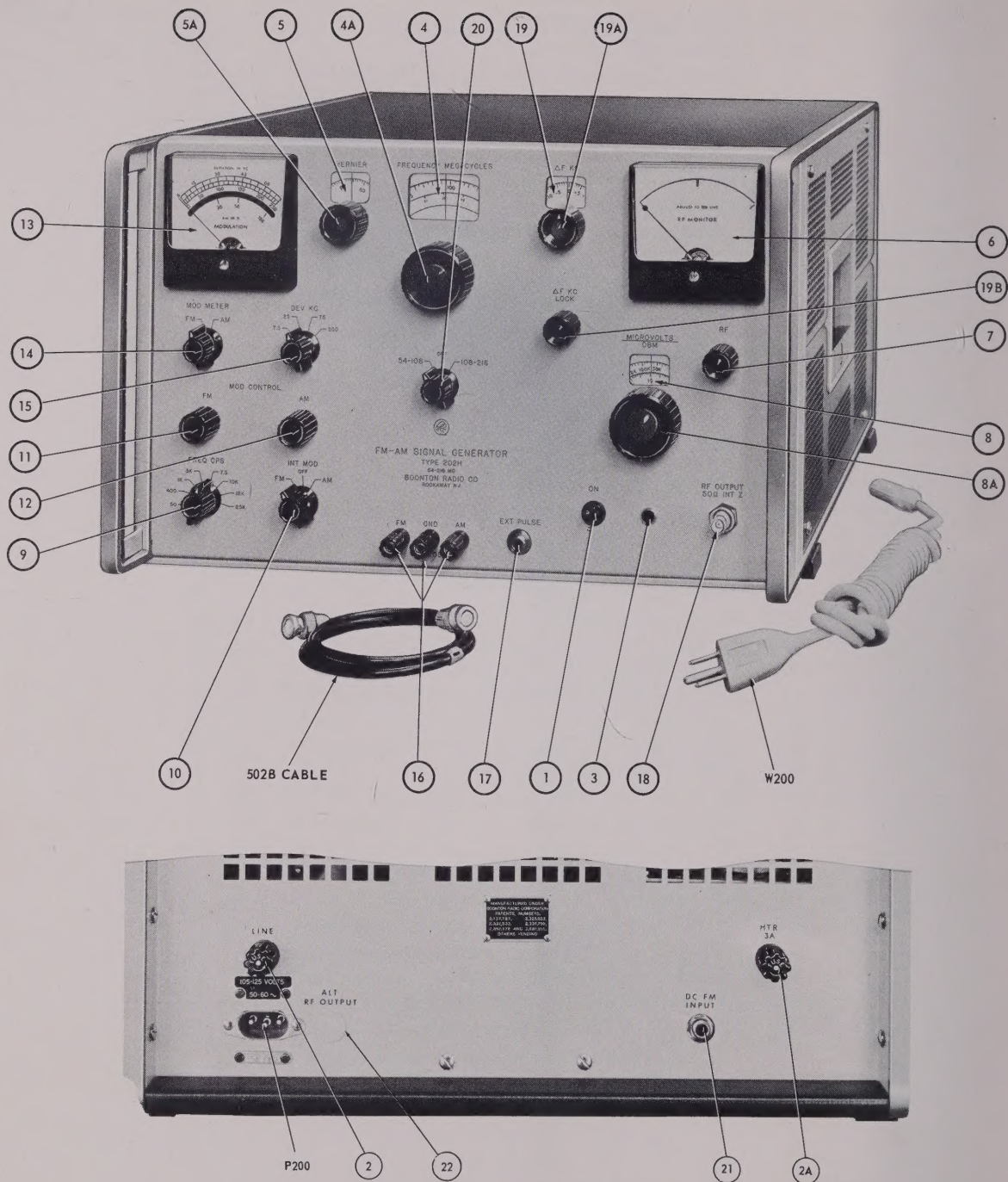


Figure 1. Operating Controls and Layout

1. Power Switch
2. Fuse (AC Line)
- 2A. Fuse (Filament)
3. Pilot Light
4. Main Frequency Dial
- 4A. Main Frequency Control
5. Vernier Frequency Dial
- 5A. Vernier Frequency Control
6. RF Monitor Meter

7. RF Control
8. RF Output Attenuator Dial
- 8A. RF Output Attenuator Control
9. Modulating Oscillator Frequency Selector
10. Internal Modulation Selector Switch
11. FM Deviation Control
12. Amplitude Modulation Control
13. Modulation Meter
14. Modulation Meter Switch

15. Deviation Range Switch
16. External Modulation Input Terminals
17. External Pulse Modulation Jack
18. RF Output Jack
19. Electronic Vernier Dial
- 19A. Electronic Vernier Control
- 19B. Electronic Vernier Dial Lock
20. RF Range Switch
21. DC FM Input
22. Alternate RF Output

SECTION I DESCRIPTION

GENERAL

The Type 202H FM-AM Signal Generator covers the frequency range from 54 to 216 mc and is designed for the testing and calibration of FM receiving systems in the areas of broadcast FM, VHF, TV, mobile, and general communications. The generator consists of a four-stage RF Unit, together with a modulating oscillator, metering circuitry, and power supply, all housed in a single cabinet which may be readily adapted for rack mounting.

The RF Unit consists of a variable frequency oscillator, a reactance tube modulator, a frequency doubler, and an output amplifier/doubler stage. The modulator is especially designed for minimum distortion and operates in conjunction with the electronic vernier to provide changes in RF output frequency as small as 10 cps, with indications in 1 kc increments. The RF output is fed through a precision, variable attenuator; automatic RF level set is incorporated which maintains "red line" on the RF monitor meter over the entire range of output frequencies and levels. The RF Unit is shock mounted for minimum microphonism.

An internal audio oscillator provides a choice of eight frequencies which may be used for either frequency or amplitude modulation. A modulation meter, responding to the average value of modulating signal indicates FM deviation. A detected signal is used for percent AM indications. Both FM and AM readings are calibrated for sine-wave modulation.

A completely solid-state power supply furnishes all necessary operating voltages.

OPERATING CONTROLS AND LAYOUT

A front and rear view of the instrument with all of its controls is shown in Fig. 1. All of the controls for operation of the 202H are located on the

front panel. Instrument front panel designations are shown within quotation marks.

1. Power Switch

This switch applies power to the circuits when in the "ON" position.

2. Fuse (AC LINE)

This fuse in the ac line is located on the back panel of the instrument (3 amp. for 115 v input, 1½ amp. for 230 v input).

2A. Fuse (Filament)

This fuse (3 amp.) in the dc filament line is located on the back panel of the instrument.

3. Pilot Light

4. Main Frequency Dial "FREQUENCY MEGACYCLES"

The Main Frequency Dial is calibrated from 54-108 mc (in increments of 0.5 mc) and 108-216 mc (in increments of 1.0 mc). A secondary or logging scale is divided into 23 equal parts for use with the Vernier Frequency Dial (5).

4A. Main Frequency Control

The Main Frequency control operates the Main Frequency Dial (4).

5. Vernier Frequency Dial "VERNIER"

This dial is divided into 100 divisions and is coupled to the Main Frequency Dial through a 24:1 gear train, providing a total of approximately 2300 logging divisions over the tuning range. A logging curve is shown in Fig. 2.

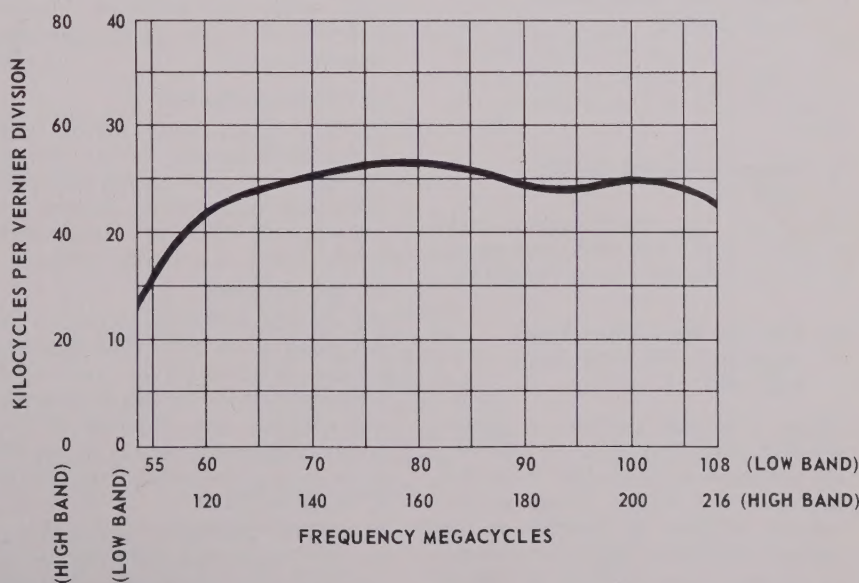


Figure 2. Logging Scale

5A. Vernier Frequency Control

The Vernier Frequency Control operates the Vernier Frequency Dial (5) and the Main Frequency Dial (4).

6. RF Monitor Meter "RF MONITOR"

The RF Monitor Meter is used to standardize the input power level to the attenuator. In operation, the meter pointer is set to the center of the red calibration line on the meter scale.

7. RF Control "RF"

This adjustment sets the RF Monitor Meter (6) to the proper reference level such that the output attenuator calibration is direct reading for a 50-ohm termination.

8. RF Output Attenuator Dial "MICROVOLTS/DBM"

The RF Output Attenuator Dial is calibrated directly in (a) microvolts and (b) decibels below 1 milliwatt output to a 50 ohm load. It is standardized by setting the pointer of the RF Monitor Meter (6) to the center of the red calibration mark on the meter scale.

8A. RF Output Attenuator Control

The RF Output Attenuator Control operates the RF Output Attenuator Dial (8).

9. Modulating Oscillator Frequency Selector "FREQ CPS"

This control selects any one of eight fixed audio frequencies between 50 cps and 25 kc for either frequency or

amplitude modulation.

10. Internal Modulation Selector Switch "INT MOD"

This switch connects the internal modulating oscillator for either frequency modulation or amplitude modulation. The OFF position disables the oscillator, but the panel terminals are connected, permitting external AM and FM.

11. FM Deviation Control "MOD CONTROL-FM"

A continuously variable control for adjusting the frequency deviation on any of the four internal ranges: 0-7.5 kc, 0-25 kc, 0-75 kc, 0-250 kc; or for external modulation.

12. Amplitude Modulation Control "MOD CONTROL-AM"

A continuously variable control for adjusting the amplitude modulation level when either the internal AF oscillator or an external source is used.

13. Modulation Meter "MODULATION"

The Modulation Meter has three scales providing four FM deviation ranges and one amplitude modulation range; 0-7.5 kc deviation in 0.5 increments, 0 to 25 kc deviation in 1 kc increments, 0 to 75 kc deviation in 5 kc increments, 0 to 250 kc in 10 kc increments, 0-100% amplitude modulation with calibration marks at 30%, 50%, and 100%. 100% AM is specified only when an external modulating oscillator is used.

14. Modulation Meter Switch "MOD METER"

With this control the Modulation Meter (13) may be switched to indicate the amount of FM or AM present on the signal.

15. Deviation Range Switch "DEV KC"

This rotary type switch selects four modulation meter FM deviation ranges: 0-7.5 kc, 0-25 kc, 0-75 kc, and 0-250 kc.

16. External Modulation Input Terminals "FM GND AM-EXT OSC"

These terminals provide a means whereby an external source of modulating voltage may be applied to the instrument. The output voltage of the internal oscillator is available at the external modulation input terminals for oscilloscope synchronizing or other purposes.

17. External Pulse Modulation Jack "EXT PULSE"

The Pulse Modulation Jack is provided to permit direct connection of an external modulation voltage source to the screen of the final RF stage for pulse or square wave modulation. When this connection is made the internal circuits are disconnected from the screen element.

18. RF Output Jack "RF OUTPUT 50Ω INT Z"

This BNC Type connector makes the generator RF signal available for use.

19. Electronic Vernier Dial "ΔF KC"

The Electronic Vernier Dial is calibrated to ± 30 kc for electronically shifting the output frequency in small increments. The total range of the control associated with this dial is ± 40 kc minimum. The Electronic Vernier Control knob (19A) is set for the electrical center of the control when the arrow points toward the top of the instrument (vertical). For least FM distortion, the knob arrow should be vertical.

19A. Electronic Vernier Control

The Electronic Vernier Control operates the Electronic Vernier Dial (19).

19B. Electronic Vernier Dial Lock "ΔFKC LOCK"

The Electronic Vernier Dial Lock is used to mechanically zero the Electronic Vernier Dial (19). The dial is set to a desired reference indication and then locked while the Electronic Vernier Control is set for the desired reference frequency.

20. RF Range Switch

The Band Switch changes the RF range of the 202H between 54 to 108 mc and 108 to 216 mc. It has an OFF position which substantially reduces the level from the RF output jack, putting the instrument in a standby condition.

21. DC FM INPUT

The DC FM INPUT is located on the back panel of the 202H. This jack may be used to introduce an external dc voltage to control the output frequency over a limited range. Typically, the sensitivity is approximately 110 kc per volt dc on the high band and 55 kc per volt dc on the low band.

22. ALT RF OUTPUT

The RF Output Jack (18) may be removed from the front panel and inserted in the hole provided on the rear panel.

This hole is covered by an easily removable plug button. This plug button is used to cover the front panel hole when the Output Jack is placed on the rear panel.

For changing the RF Output Jack and External Modulation Input Terminals from front panel to rear, a 523A Adapter must be used for rack mounting.

SECTION II

SPECIFICATIONS

Radio Frequency Characteristics

RF RANGE:

Total Range: 54 to 216 MC

No. Bands: 2

Band Ranges: 54-108 MC 108-216 MC

RF ACCURACY:

Main Dial: $\pm 0.5\%$ *

Electronic Vernier: $\pm (10\% + 1 \text{ KC})$ *

*after one hour warm-up

RF CALIBRATION:

Main Dial: Increments of 0.5 MC (54-108MC)

Increments of 1.0 MC (108-216 MC)

MECHANICAL VERNIER:

2300 divisions through each range

ELECTRONIC VERNIER:

Increments of 1 KC over $\pm 30 \text{ KC}$ range*

*total range $\pm 40 \text{ KC}$; provision for slipping dial to place "0" at a specific frequency

RF STABILITY:

$< 0.01\%$ per hour*

*after two hour warm-up

RF OUTPUT:

Range: 0.1 μv to 0.2 volts*

*across external 50 ohm load at panel jack

Accuracy: $\pm 10\%$, 0.1 μv to 50 K μv

$\pm 20\%$, 50 K μv to 0.2 volts

Auto Level Set: holds RF monitor meter to "red line" over band

Impedance: 50 ohms

VSWR: < 1.2

Spurious Output: All spurious RF output voltages are at least 30 db below desired fundamental

RF LEAKAGE:

Sufficiently low to permit measurements at 0.1 μv

Amplitude Modulation Characteristics

AM RANGE:

Internal: 0-50%

External: 0-100%

AM ACCURACY: $\pm 10\%$ at 30% and 50% AM

AM CALIBRATION: 30, 50, 100%

AM DISTORTION:

$< 5\%$ at 30%

$< 8\%$ at 50%

$< 20\%$ at 100%

AM FIDELITY:

$\pm 1 \text{ db}$, 30 cps to 200 KC

EXTERNAL AM REQUIREMENTS:

Approx 60 volts RMS into 5000 ohms for 100% AM

Frequency Modulation Characteristics

FM DEVIATION RANGE:

Internal: 0-250 KC in 4 ranges

External: 0-250 KC in 4 ranges

FM DEVIATION ACCURACY:

$\pm 5\%$ of full-scale*

*for 400 cps sine-wave

FM CALIBRATION:

0-7.5 KC in increments of 0.5 KC

0-25 KC in increments of 1 KC

0-75 KC in increments of 5 KC

0-250 KC in increments of 10 KC

FM DISTORTION:

$< 0.5\%$ at 75 KC (100 MC and 400 cps modulation only)

$< 1\%$ at 75 KC (54-216 MC)

$< 10\%$ at 250 KC (54-216 MC)

FM FIDELITY:

$\pm 1 \text{ db}$, 5 cps to 200 KC

SIGNAL-TO-NOISE RATIO:

$> 60 \text{ db}$ below 10 kc

MICROPHONISM:

Extremely low; shock-mounted RF unit

EXTERNAL FM REQUIREMENTS:

$< 3 \text{ volts RMS}$ into 2000 ohms for 250 KC deviation

Pulse Modulation Characteristics

PM SOURCE: External

PM RISE TIME: $< 0.25 \mu\text{sec}$

PM DECAY TIME: $< 0.8 \mu\text{sec}$

Modulating Oscillator Characteristics

OSC FREQUENCY:

50 cps 7.5 KC

400 cps 10 KC

1000 cps 15 KC

3000 cps 25 KC

OSC ACCURACY: $\pm 5\%$

OSC DISTORTION: $< 0.5\%$ at FM terminals

OSC EXTERNAL OUTPUT:

5 volts approx. at external FM posts

26 volts approx. at external AM posts

Accessories

FURNISHED:

Type 502-B Patching Cable

AVAILABLE:

Type 207-H Univerter

Type 501-B Output Cable

Type 504-A Adapter

Type 505-B Attenuator

Type 506-B Patching Cable

Type 507-B Adapter

Type 508-B Adapter

Type 509-B Attenuator

Type 510-B Attenuator

Type 514-B Output Cable

Type 517-B Output Cable

Type 523A Adapter

Tube Complement

TUBES	DIODES	TRANSISTORS
3—6688	2—1N660	1—2N1136
1—6AF4A	2—1N1763	3—2N1379
2—6AW8A	4—1N1764	1—2N1533
3—6AU6A	2—1N1581	
1—6BK7A	1—S1029	
1—6AQ5A		
1—6DJ8		

SECTION III

OPERATING INSTRUCTIONS

INSTALLATION

Remove the type 202H Signal Generator from its shipping carton and place it in position on a test bench. If the instrument is to be mounted in a rack, refer to Fig. 4 for mounting the accessory hardware.

CAUTION: Shipping support screws¹ should be disengaged before operation of the 202H Signal Generator. Use the procedure given below.

Removal of Shipping Support Screws

1. Remove top cover of the instrument.
2. Disengage the four shipping support screws (Fig. 5) by turning the screws clockwise until the washers lock on the threaded hexagonal spacer. Use a #8 (5/64") hex wrench. The RF Unit should float freely.
3. Replace top cover of the instrument.

SECURE RF UNIT WITH
DEVICES PROVIDED
WHENEVER SHIPPING
THE 202H

Connect the power cord to the power socket at the rear of the 202H. Then connect the power cord to a 105-125v, 50 or 60 cps source. An input voltage switch is on the chassis at the right rear of the instrument and may be operated to use the 202H with a 210-250v, 50 or 60 cps source. (This switch is accessible only after removal of the top cover.)

NOTE: Reverse voltage plate on back panel to agree with switch and change fuse as described under "2. Fuse (AC Line)"

Set the power switch to the "ON" position and allow unit to warm up a minimum of two hours for stabilized output frequency. However, all other operations will be normal after a fifteen minute warm up.

¹—In instruments with serial numbers up to 5718 wooden shipping blocks are used. Blocks may be removed after removal of shipping screws as indicated in Fig. 5.

INSTRUCTIONS

1. REMOVE TILT STAND, FEET, AND PLASTIC TRIM.
2. ATTACH TRIM STRIP AND FLANGES, KEEPING LARGE NOTCH ON FLANGE TO INSTRUMENT BOTTOM.

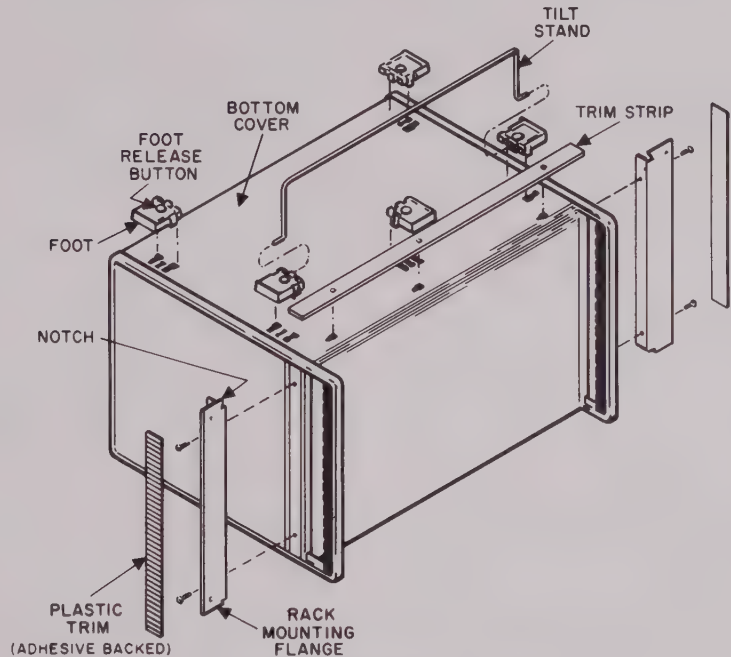


Figure 4. Rack Mounting Instructions

PRELIMINARY INSTRUCTIONS

(See Fig. 1)

Operation of the RF control (7) should cause the pointer of the RF Monitor Meter (6) to move. After initial adjustment, the meter should remain within the red line reference mark over the entire 54 to 216 mc range of the instrument. This is an indication that the RF oscillator, RF

Amplifiers, and AGC Amplifiers are working properly.

To check the FM and AM modulation systems, turn the Internal Modulation Selector Switch (10) to "FM", the Modulation Meter Switch (14) to "FM" and the Deviation Range Switch (15) to 7.5 kc, 25 kc, 75 kc, or 250 kc. Operating the FM Deviation Control (11) in a clockwise direction should cause the Modulation Meter (13) to read increasing deviation. Switch the Modulation Selector Switch (10) to "AM", the Modulation Meter Switch (14) to "AM"; rotate the Amplitude Modulation Control (12) clockwise. The Modulation Meter (13) should read the per cent of amplitude modulation present and should be capable of reaching 50%. (100% AM is only specified when using an external source of modulating frequency.)

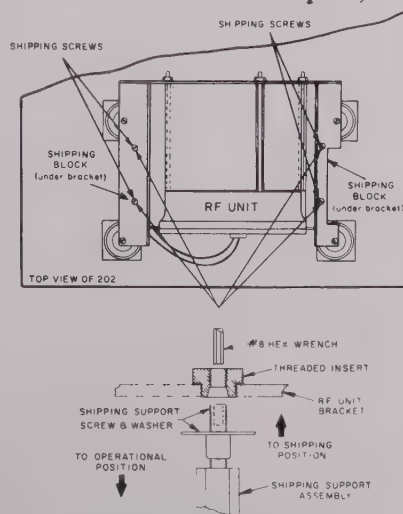


Figure 5. Shipping Supports

USING THE SIGNAL GENERATOR

Frequency Modulation

Four frequency deviation ranges: 0-7.5 kc, 0-25 kc, 0-75 kc, and 0-250 kc are provided, each continuously adjustable. Calibrated increments are 0.5 kc on the 7.5 kc range, 1 kc on the 25 kc

range, 5 kc on the 75 kc range, and 10 kc on the 250 kc range. With an external modulating source, approximately 2.5 volts rms into 2K ohms is required for 250 kc deviation.

Amplitude Modulation

0-50% Modulation: Utilizing the internal audio oscillator or an external modulating oscillator, amplitude modulation may be obtained over the range of 0-50% with meter calibration points provided at 30% and 50% modulation points.

0-100% Modulation: Using an external modulating oscillator capable of 60 volts rms into 5000 ohms, the RF carrier may be amplitude modulated to 100%. For this purpose, the modulation meter has a scale calibration point at 100%.

Pulse Modulation: A front panel jack is provided which permits direct connection of an external modulation voltage source to the screen of the final stage for pulse or square wave modulation. When this connection is made, internal circuits are disconnected from the screen element. Approximately 40 to 55 vdc are required to maintain the carrier at its normal level. Application of approximately -7.5 volts will give maximum ON-OFF ratio. The 7.5 volt negative swing can be achieved by a small dc supply in series with the pulse source or by ac coupling a pulse with a suitable duty cycle. Under these conditions, the ON-OFF ratio exceeds 30 db (See Fig. 6 for typical data).

In order that the attenuator system may accurately indicate the rms output voltage at pulse peak, it is necessary to equate the positive pulse amplitude to the dc screen voltage at the particular carrier frequency of interest. This can be done with a good direct coupled oscilloscope (bandwidth determined by type of pulse employed). With the oscilloscope on 5v/cm, connect it to the tip of the "Ext. Pulse" jack without breaking the internal contact. The oscilloscope will then read the dc final amplifier screen voltage (typically 40 - 55 vdc). Then, connect the pulse source (disconnecting the internal circuit) and set its positive amplitude to the same voltage as above.

Simultaneous Modulation

For certain tests, simultaneous FM and AM is sometimes desired. The 202H FM-AM Signal Generator, in

combination with an external low distortion modulating oscillator, may be used for this purpose, provided that the modulating oscillator is capable of developing at least 3 volts rms across a 2K ohm load; the most severe requirement for 250 kc deviation.

In use, the external modulating oscillator is connected to the FM external Modulation Input Terminals (16), the Internal Modulation Selector Switch (10) set to AM, and the levels of each type of modulation independently set on the Modulation Meter (13) by operation of the Modulation Meter Switch (14), FM Deviation Control (11), and Amplitude Modulation Control (12). For maximum accuracy, the % AM should be set first with the external FM source off, since the % AM meter will read the small residual AM caused by high deviation FM.

CAUTION: Use of an external audio oscillator for AM, with the INTERNAL MODULATION OSCILLATOR switched to FM, will result in interaction between modulation circuits when both oscillators are operating at or near the same audio frequency.

Simultaneous FM at two modulation frequencies or simultaneous AM at several modulation frequencies is also possible when multiple external oscillators are used. In practice the external modulating oscillators are connected to the External Modulation Input Terminals (16), and the Modulation Selector Switch is set to OFF.

OUTPUT CONNECTIONS

The method of connecting the load to the 202H Signal Generator must be considered to insure proper interpretation of results, and the following discussion is offered as an aid to the user.

It is convenient to represent a signal source in terms of its open circuit voltage and internal impedance. Thus, a signal source or an antenna can be represented as in Fig. 7. For simplicity, only the case where source and load impedance are resistive will be considered. This represents the output connections when the Type 502B cable is used.

For purposes of rating sensitivity, the input to a receiver might have been defined initially either as the open circuit source voltage $2E$ or the voltage

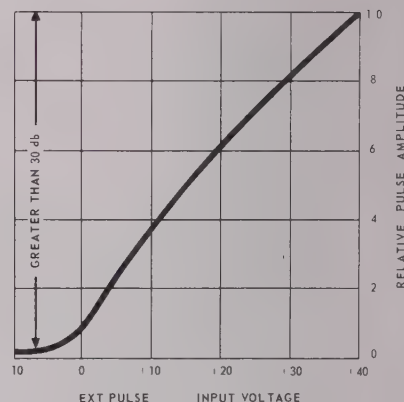


Figure 6. 202H Pulse Modulation Characteristics

actually across the receiver terminals. The Institute of Radio Engineers has established the former method as standard and defined receiver input in terms of the open circuit voltage of the source.¹

The impedance of the signal source employed to test receivers should be equal to the impedance of the antenna with which the receiver is designed to operate. Note that in this case the voltage actually across the receiver terminals is

$$\frac{2E}{2} = E \text{ (Receiver input impedance equal to source impedance).}$$

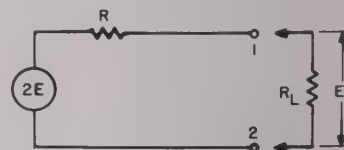


Figure 7. Signal Source Representation

The 202H signal generator is calibrated to read the voltage "E" of Figs. 7 through 11.

Accessories for physically connecting the instrument to the load are described in the following:

1—IRE STD 17.S1 Standards on Radio Receivers: Methods of Testing Frequency Modulation Broadcast Receivers, 1947. Adopted by ASA.

IRE STD 17.S1 Standards on Radio Receivers: Methods of Testing Amplitude-Modulation Broadcast Receivers, 1948. Adopted by ASA.

IRE STD 17.S1 Standards on Television: Methods of Testing Monochrome Television Broadcast Receivers, 1960. Adopted by ASA.

502B Patching Cable

Provides simple connection for a matched load. (See Fig. 7.)

501B Output Cable

The 501B Cable attached to the 202H is illustrated by Fig. 8, where R_2 is the 50-ohm termination of the 501B Cable.

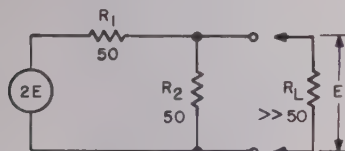


Figure 8. Output Circuit of 202H with 501B Output Cable Attached

The equivalent circuit (Fig. 9) is readily determined by applying Thevenin's theorem. This arrangement is recommended for general use where it is desirable to connect the 202H output to an input circuit of much higher impedance than 50 ohms. The attenuator, of the 202H will read the open-circuit output directly.

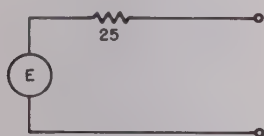


Figure 9. Equivalent Output Circuit of 202H with 501B Output Cable Attached

505B 6 db Pad

This pad is used as a dummy antenna in testing unbalanced receivers with a 50-ohm input as shown in Fig. 10.

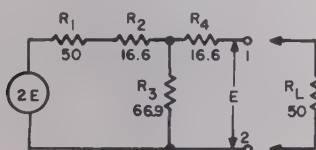


Figure 10. 505B T-Pad (Attenuator) Circuit

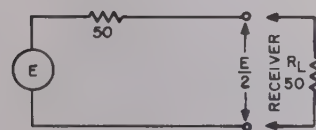


Figure 11. 505B T-Pad (Attenuator) Equivalent Circuit

The open-circuit voltage appearing across terminals 1 and 2 is by Ohms law equal to E , half of the source volt-

age. Applying Thevenin's theorem, the equivalent circuit of Fig. 11 is obtained, and thus the attenuator dial of the 202H reads receiver sensitivity directly for the assumed standard output. This circuit is well matched and the 202H attenuator reads the open circuit source voltage as specified in footnote 1 for receiver sensitivity measurement.

509B 20 db T-Pad

The 509B pad, like the 505B, may be used as a dummy antenna, except that the open-circuit voltage, which is a measure of receiver sensitivity (equivalent source voltage), is one-fifth the 202H attenuator dial reading. The source impedance is 50 ohms.

SECTION IV

THEORY OF OPERATION

GENERAL

The 202H FM-AM Signal Generator shown in the block diagram (Fig. 12) covers a frequency of 54 to 216 mc, inclusive. This instrument is designed for use in the testing and calibration of FM receiver systems in the entertainment field (FM radio and VHF-TV), mobile and general communication.

The generator consists of an RF Unit, which is the radio frequency generating portion of the instrument; modulation circuitry; an output monitoring system; an internal modulating oscillator; and a power supply.

RF UNIT

The RF Unit is a four-stage frequency generating subassembly. It contains an RF Oscillator, 1st frequency doubler, 2nd frequency doubler or amplifier, and reactance modulator.

The RF oscillator V101 (6AF4A) is a tuned plate oscillator covering the range of frequencies from 27 mc to 54 mc, inclusive. Tuning is accomplished by means of C109 which is part of the ganged tuning capacitor also including C101, C115, and C123. (See Fig. 70.)

The first frequency doubler V102 (6688) has an output frequency range of 54 to 108 mc, inclusive. This stage acts as a buffer to isolate the frequency source from the output. The high gain of this stage supplies sufficient driving voltage for saturation and limiting action in the second frequency doubler/amplifier (V103) resulting in a constant amplitude output frequency.

The output tube V103 (6688) is used as a doubler or as an amplifier depending on the position of the 202H RF range switch, thereby providing output coverage from 54 to 216 mc.

The reactance modulator V100 (6688) or frequency modulator is actually an inductive element across the tuning tank of the RF oscillator (V101). In order to maintain constant frequency deviation sensitivity over the entire tuning range of the instrument, the amount of inductance produced by V100 is made to vary directly as the carrier frequency. This is accomplished by the proper attenuation characteristic of a bridged-tee 90° phase shift network consisting primarily of R101, C101, R100 and C_{sp} with associated circuitry as shown in Fig. 13. Although

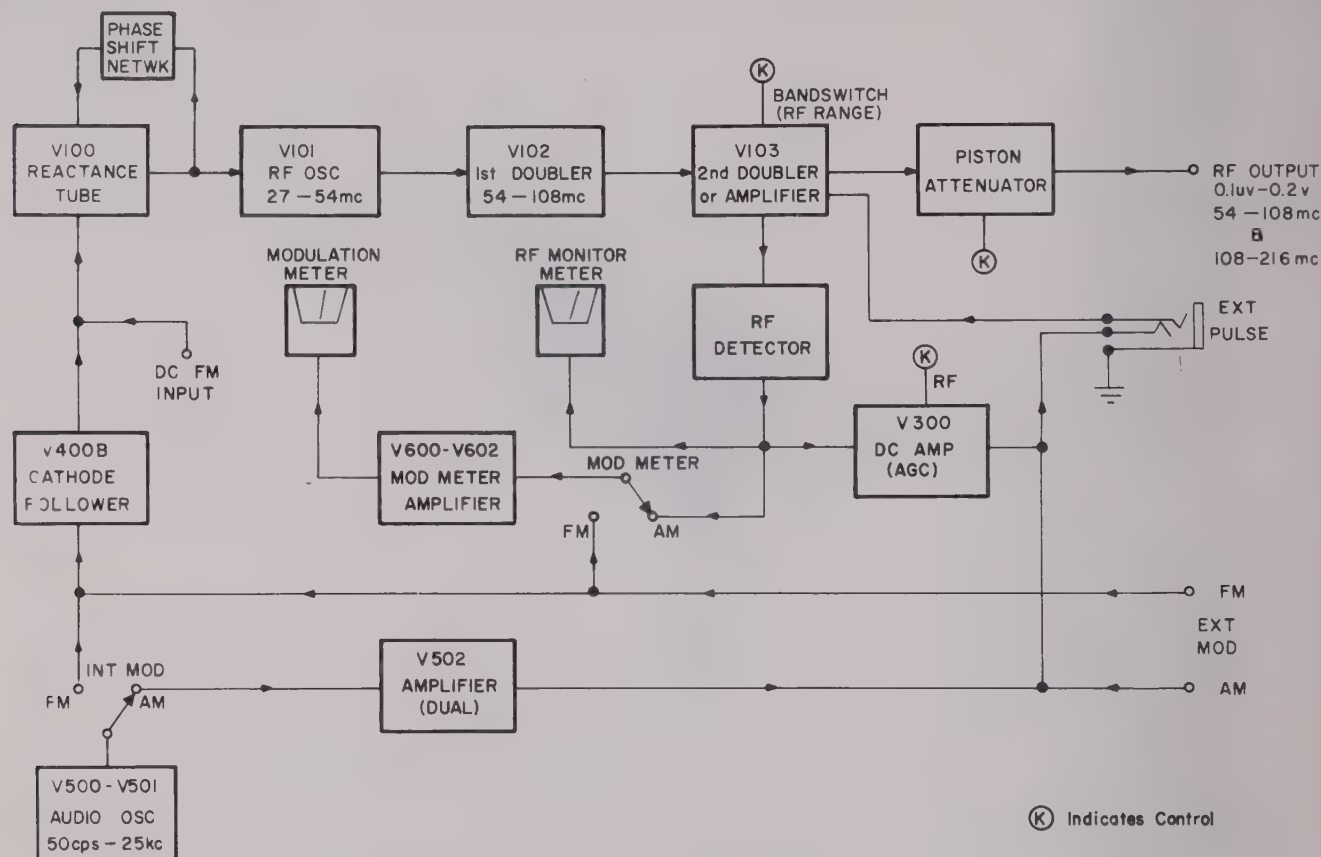


Figure 12. 202H Block Diagram

this circuit arrangement is capable of producing fairly constant deviation with fixed components. C101 is made variable and ganged with the oscillator tuning capacitor to provide the constancy of frequency deviation required in a precision signal generator.

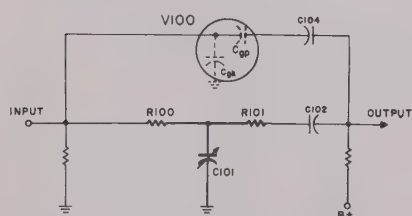


Figure 13. Bridged-Tee Phase Shift Network

Fixed bias is supplied through variable resistor R107 to establish the operating point of V100. RF signals are bypassed at the cathode by C126. Additional modulation frequency gain stability, by means of negative current feedback, is achieved by the small value of bypass capacitor C126.

For FM, V100 is modulated by applying the modulating voltage to the grid of the tube through Section 5 of the RF Filter 308645.

For AM, V103 is modulated by applying the modulating voltage from either the internal oscillator or an external source to the screen grid of the tube. The screen grid dc voltage is supplied from the AGC amplifier.

For pulse modulation, the screen grid of V103 is modulated as with AM, except that no internal voltages are supplied to the screen grid, so all voltages must be supplied through the EXT PULSE jack on the front panel of the instrument.

A piston type RF attenuator is inductively coupled to the tank coil of the modulator by means of a two turn pick-up loop in the same plane as the loop of the tank coil. A 50-ohm carbon film resistor, in series with the loop, provides a 50-ohm source impedance. At the point where the loop connects to the output coaxial cable there is an

impedance compensating circuit composed of a 50-ohm resistor and a capacitor in series to ground (Fig. 14). The compensating circuit tends to draw current of a leading phase when the loop phase is lagging, resulting in the maintenance of good low VSWR source impedance from the attenuator output.

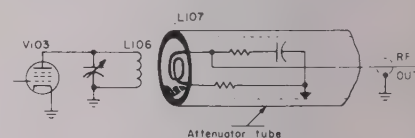


Figure 14. Piston Attenuator Circuit

The pickup loop of the attenuator is continuously adjustable along the axis of the attenuator tube by means of a rack and pinion drive.

The Transverse Electric (TE₁₁) wave amplitude is held constant by the AGC circuit and is logarithmically attenuated in the "waveguide-below-cutoff" attenuator tube.¹

1—"Technique of Microwave Measurements," Vol. 11, Radiation Lab. Series, Chapt. 11, Page 686.

MODULATION CIRCUITS

The metering of the frequency modulation is accomplished by sampling the input voltage to the cathode follower which drives the reactance modulator. The diagram (Fig. 15) shows the frequency modulation and metering of the 202H.

In contrast to the metering of the FM function, the AM is metered by sampling the modulated RF, detecting, and measuring the recovered signal. This is indicated in Fig. 16.

— Modulation circuitry
 --- Metering circuitry

to the screen grid of the RF Unit output tube, which is paralleled by the AGC circuitry, and provide sufficient voltage gain to produce a minimum of 50% AM with a good safety factor at all internal modulation frequencies.

much as the oscillator is still operating, there will be a small amount of RFI leakage through the output tube inter-electrode capacitance. In this curoff condition the output signal will be approximately 30 db below normal. See Section III—Using the Signal Generator, Pulse Modulation.

The detector diode (CR 101) in the plate circuit of the RF Unit output stage serves two functions:

- (1) It supplies a dc level (Proportional to the RF carrier amplitude) to the RF Level Monitor Meter and AGC Circuits.
- (2) Supplies a demodulated AM (ac) signal to the Modulation Meter circuit for indicating percent AM.

The diagram illustrates the Modulation Section of a radio receiver. It features several interconnected blocks:

- V103 2nd DOUBLER or AMPLIFIER (MODULATOR)**: Receives **RF IN** and sends signals to the **RF DETECTOR** and the **MOD CONTROL** line.
- RF DETECTOR**: Receives signals from the modulator and sends them to the **MOD METER AMP** and the **V300 DC AMP (AGC)**.
- V300 DC AMP (AGC)**: Receives signals from the RF detector and sends them to the **MOD CONTROL** line.
- MOD METER AMP**: Receives signals from the RF detector and sends them to the **MODULATION METER**.
- MODULATION METER**: A meter symbol representing the modulation measurement.
- V500-V501 AUDIO OSCILLATOR**: Provides an audio signal to the **V502 AMPLIFIER (DUAL)**.
- V502 AMPLIFIER (DUAL)**: Receives signals from the audio oscillator and the **MOD CONTROL** line, and outputs to the **EXT AM** terminal.
- MOD CONTROL**: A line that carries modulation control signals from the modulator and AGC amplifier to the final amplifier stage.

 The legend indicates that solid lines represent the **Modulation circuitry** and dashed lines represent the **Metering circuitry**.

15

For accurate indication of % AM with the RF Monitor Meter set to "Red Line", the ratio of ac output (AM meter) to dc output (RF Monitor Meter) must be held constant, requiring a flat frequency response for the demodulated AM signal for modulation frequencies up to the specified AM fidelity limit of 200 kc. The flat response is obtained by first, isolating the diode and meter circuits using a resistive divider (R116, R316) to reduce the effective diode source impedance to the filter and stray capacitance on the detected AM lead. A shunt peaking inductor (L 300) further flattens the response. Without the inductor the demodulated output would be attenuated at the higher modulation frequencies.

The dc level (beyond the filter) having been attenuated by the resistive divider is not sufficient to produce satisfactory AGC operation.

The second filter lead, therefore, brings a signal to the AGC circuit having sufficient change in dc with a change in RF Level to produce proper AGC loop gain.

MODULATING OSCILLATOR

The AF oscillator employed is quite free of distortion, having, in general, total harmonic content of less than 0.5% internally.¹ The conventional Wein Bridge type R-C oscillator is used. Approximately 26 volts rms is available from the AM-External Modulation Input Terminals for oscilloscope syn-

1—See Section VI — Maintenance, for Harmonic Distortion measurement.

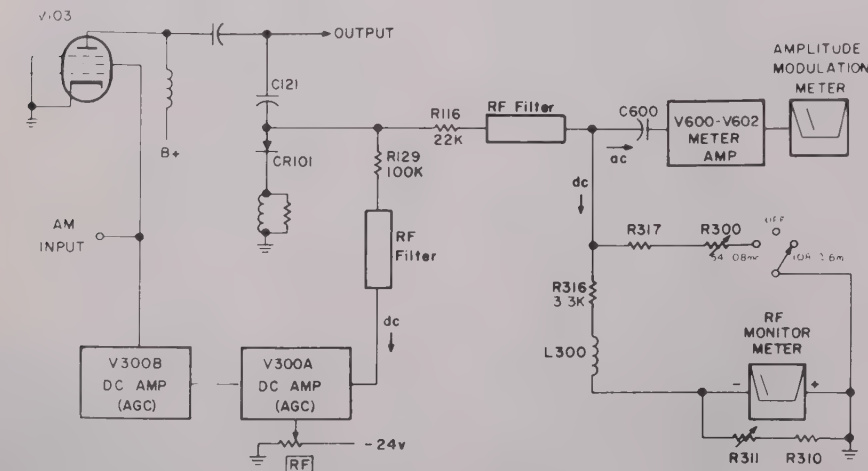


Figure 18. Output Monitor System

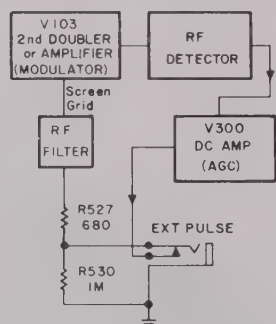


Figure 17. Modulation — Pulse

chronization or sweep. The output is controlled by adjustment of R510 which regulates the amount of negative feedback voltage applied to the cathode of V500.

The specific modulation frequencies supplied by the 202H internal audio oscillator were chosen to give general coverage of the audio range. The frequencies, 400 cps and 1 kc, are industry standards for measurement.

DC FM INPUT

The instantaneous voltage on the grid of the reactance modulator tube (V100) determines the instantaneous output frequency of the 202J. Referring to Fig. 19, it will be noted that either an ac voltage (by way of the cathode follower V400B) or a dc voltage (through the DC FM INPUT jack) can be supplied to the reactance modulator (V100). There are two sources of dc. First, is the small incremental frequency deviation voltage supplied by the ΔF KC control. Secondly, the external dc voltage can be supplied from an ex-

ternal AFC system or from an external frequency plotter system. The frequency sensitivity of the DC FM INPUT jack is approximately 1 volt dc for 110 kc deviation on the high band, and approximately 1 volt dc for 55 kc deviation on the low band. The impedance is 22K ohms. The time constant of the DC FM INPUT is approximately 1 second.

POWER SUPPLY

The 202H power supply utilizes solid-state components in the circuitry. Silicon diodes are used in the full-wave bridge rectifier and the dc filament supply. All regulation is done with semiconductors; i.e., transistors and zener diodes.

The +150 volt regulator is shown in Fig. 20. It is identical in principle to the conventional "series regulator" with voltage reference (CR210), feedback amplifier (Q202, Q203, and Q204), and series control element (Q201). Since Q201 is connected between the negative 100 volt input and ground, all regulator voltage variations must occur across Q201, R200, and R201 if the +150 to ground voltage is to be independent of voltage variation as the line voltage or load current vary. CR209 limits the maximum voltage across Q201 and R200-R201 limit the series current. Q202 is a current amplifier which causes the collector current of Q201 to increase (resistance of emitter-collector circuit drops) for a small increase in Q202 base current. The base current of Q202 increases as its base potential gets more negative since it is a PNP device. Thus, if Q204 had zero collector current, Q202 and Q201 would be saturated (i.e., large collector current, low collector-emitter voltage) and E_0 would approach E_{in} . Thus, decreasing Q204 collector current increases E_0 .

Now, consider the amplifier composed of Q203 and Q204. Since CR210 represents a stable reference voltage the collector current of Q204 must depend only on its emitter current which is inversely controlled by the emitter current of Q203, which in turn depends on the value of E_0 and the setting of R207. If E_0 decreases, the base current (and hence emitter current) of Q203 increases, thus decreasing the emitter current (and hence collector current) of Q204. Since we have seen before that a decreased collector current in Q204 increases E_0 , regulation will occur. Since

SECTION V OPERATIONAL GUIDE

INTRODUCTION

The Operational Guide is a section devoted to expanding the specifications of the 202H. This added information should assist in providing more accurate results as the capabilities and limitations of the Signal Generator are expanded upon.

PISTON ATTENUATOR

The RF Output Attenuator consists of a circular "waveguide-below-cutoff" operating in the TE_{11} Mode. This type of attenuator exhibits a theoretical 32 db attenuation for each unit of travel of the pickup probe equal to the diameter (.700 inches) of the attenuator waveguide. At levels above 50K microvolts (approximately), the attenuator pickup probe begins to emerge from the waveguide and the attenuation characteristic begins to depart from the theoretical value shown above. Thus, maximum linearity is apparent in the region below 50K microvolts and the greatest accuracy will be realized in that range. This phenomenon is reflected in the 202H specifications.

The pickup probe in the attenuator is compensated as indicated in the Theory of Operation Section. This compensation maintains a more constant output impedance resulting in a low VSWR, the maximum specified being 1.2. With a VSWR of 1.2, the associated reflected power loss would be less than 0.035 db which is considered negligible.

The dial calibration is indicative of the average RF power output. When employing a Bolometer to calibrate this generator, the carrier should be unmodulated. Amplitude modulation, with its resulting sidebands, will tend to increase the average power output, approaching a 50% increase as the carrier is modulated at 100%. Frequency modulation, however, will have no effect on the output power level, except for the effect of residual AM on FM. See FM operation.

FREQUENCY DRIFT DATA

The specified frequency stability of the 202H Signal Generator is 0.01% or less per hour. This stability can be obtained after a two-hour warm-up

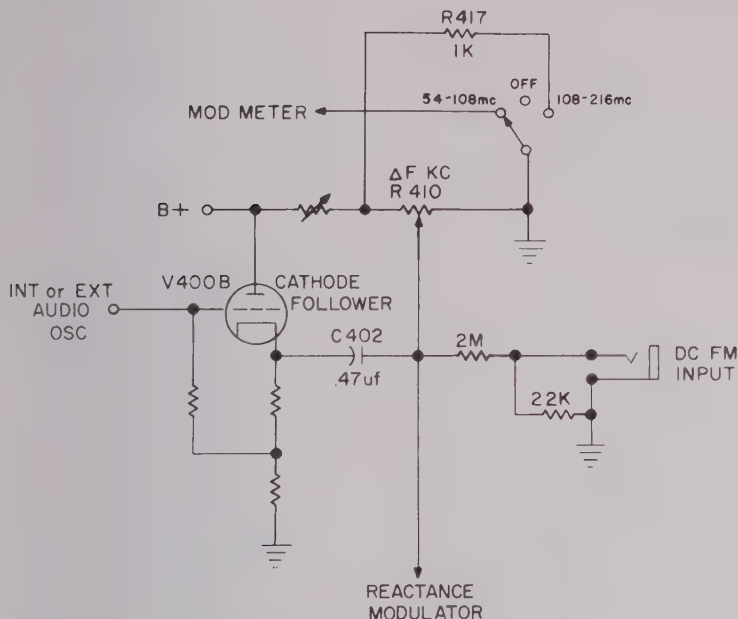


Figure 19. DC FM System

the current gain from the base of Q203 to the collector of Q201 is high, the output E_o will depend only on the setting of R207, and the drop across CR210. C204 and C210 reduce the high frequency gain of the amplifier to keep it stable.

The use of two transistors, Q203 and Q204, is to balance their base-emitter voltage change with temperature variation, thus, achieving the stability

required.

A second dc voltage from the power supply is for use in the RF Unit and V400 filaments. It utilizes two silicon diodes as a full-wave rectifier with a zener diode and a transistor to maintain the proper regulated output of 7.3 volts dc. This is dropped to 6.3 volts in the RF Unit for V100 to V103 by the dc resistance in the RF filter. This function is provided by CR211 for the FM cathode follower, V400.

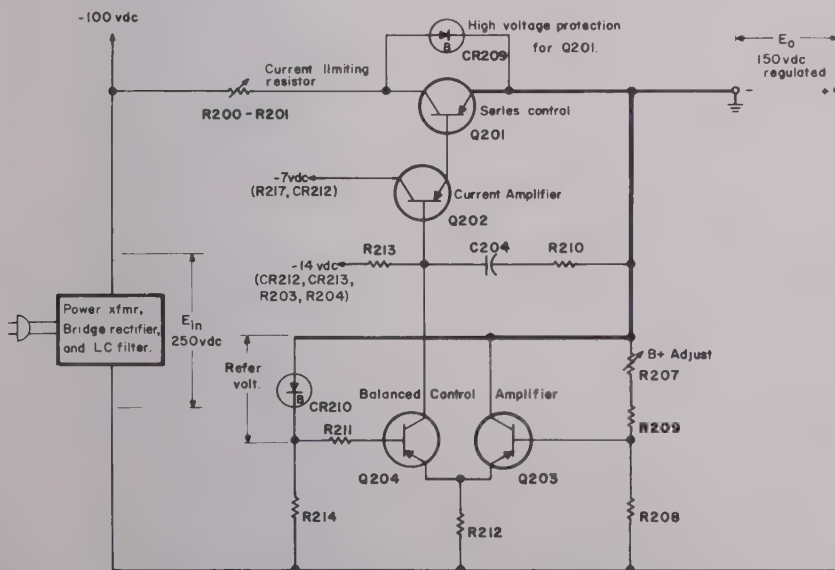


Figure 20. Power Supply B+ Regulation Circuit

period, under stable ambient temperature conditions. Typical drift data for a 202H at 110 mc in the high band is shown in Figure 21. After the 3rd hour the typical drift is .003% per hour and after 24 hours it is less than .001% per hour. After 24 hours a unit operating on a regulated line, in quiet, stable ambient temperature surroundings exhibits a short-term drift of approximately .0003% per minute (300 cps at 100 mc). This is typical data, however and does not change the published specifications since the 0.01% per hour figure will be approached at some frequencies by some instruments.

FM OPERATION

In FM operation the 202H Modulation Meter circuitry samples the input modulation signal. The average reading Modulation Meter is calibrated to indicate the resulting peak deviation for a Sine Wave modulation signal.

Deviation indications for a complex waveform such as a multiplex stereo signal will, therefore, not be correct. However, it is possible to have an accurate deviation indication when using a complex waveform source such as the BRC 219A Stereo Modulator with its peak-to-peak reading meter indicating "Percent System Deviation." The meter in the 219A can be calibrated to read 100% system deviation corresponding to a 75 kc sinewave deviation indication on the 202H Modulation Meter. Then for complex waveforms the 219A meter will indicate percent system deviation based on 75 kc equaling 100%.

The Deviation Range Switch (DEV KC) attenuates the modulation signal for both internal and external FM. The greatest sensitivity for external FM

operation can, therefore, be obtained with the Deviation Range Switch in the 250 KC position.

Figure 22 shows a typical 202H FM channel fidelity characteristic at 80 mc. The portion of the curve above 10 kc was obtained by using the "Fidelity Measurement Procedure" in Additional Information for FM Measurements, Section VI. The low frequency portion of the curve, below 10 kc, is the frequency response of the FM channel measured between the front panel terminals (EXT OSC-FM) and the FM Input of the RF Unit (J102). This measurement is made with a dc coupled oscilloscope with known low frequency response. Below 10 kc the frequency response of the RF Unit and filter is almost perfectly flat.

The frequency response of the Modulation Meter increases for modulation frequencies between 10 kc and 100 kc, and decreases above 100 kc, to match the average frequency response of the FM Channel. Below 15 cps some meter correction may be necessary. At 15 cps the indicated deviation is approximately 3% low. For any individual instrument at various carrier frequencies an exact

correction curve can be obtained by measuring the FM channel fidelity and Modulation Meter frequency response. Figures 23A and 23B show typical responses of the FM channel for 100 cps and 25 kc square waves.

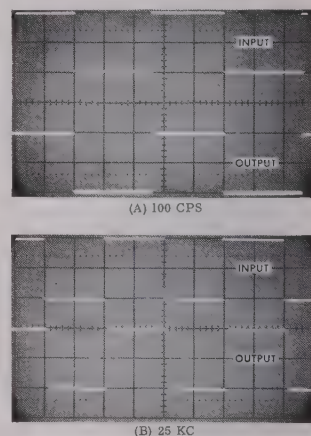


Figure 23. FM Channel Square Wave Response

The modulation meter when used in the AM position actually measures "recovered AM". Thus, after adjusting the generator in the FM mode of operation, it is possible to switch only the Modulation Meter to "AM". The meter will then read incidental AM on the carrier. Typical readings are:

1. With 75 kc deviation, the incidental AM will be less than 3%.
2. With 250 kc deviation, incidental AM will be less than 7% at the high carrier frequencies on each band and less than 15% at the low ends of the frequency bands.

A typical instrument will show less than 1 kc incidental FM with 50% AM. The amount of incidental FM will vary with carrier frequency.

FM DISTORTION

In operation, the ΔF electrical tuning actually shifts the dc operating point of the reactance tube. This same effect occurs when an external dc control

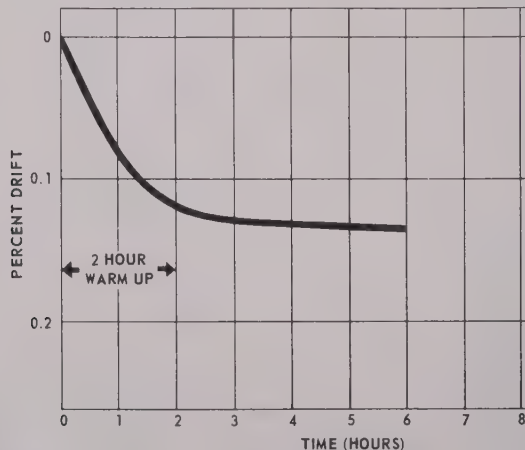


Figure 21. Long-Term Frequency Drift Characteristic Curve

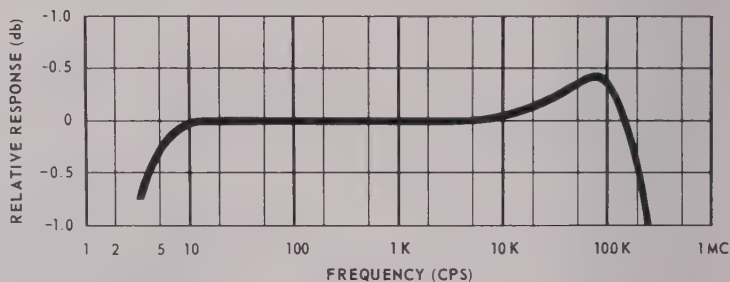


Figure 22. FM Channel Fidelity Characteristic Curve

voltage is supplied to the DC FM INPUT jack. The 202H is adjusted for minimum distortion with the ΔF control in its mid-position (knob arrow vertical) and no external dc applied.

Fig. 24 shows the DC FM INPUT characteristics of the 202H which is also the modulator characteristic. In this figure it can be seen that the distortion increases rapidly in the negative direction above 275 kc (Low Band) and 550 kc (High Band) or -5 vdc at the DC FM INPUT jack. For higher deviation (over 300 kc Low Band and 600 kc High Band) the modulator operating point should be shifted by applying a positive dc voltage to the DC FM INPUT. This will extend low distortion modulation capabilities to approximately 350 kc deviation Low Band, and 700 kc deviation, High Band.

The ΔF control and DC FM INPUT circuits do not react instantaneously, thus, sufficient time should be allowed for the instrument to stabilize. The time-constant in the ΔF tuning control and DC FM INPUT circuits is approximately 1 second.

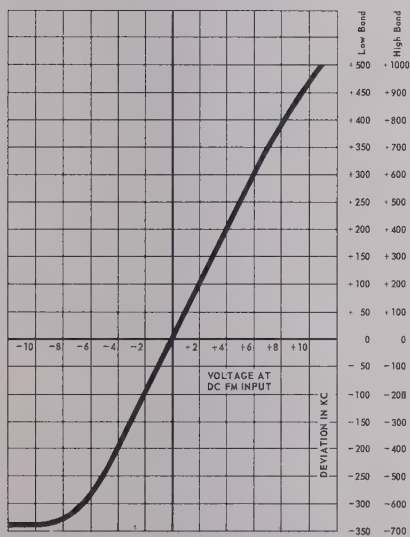
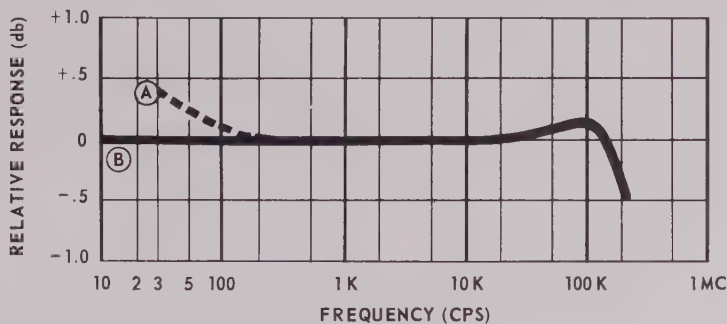


Figure 24. DC FM Input Characteristic Curve

AMPLITUDE MODULATION

The 202H employs screen grid amplitude modulation. At levels above 50% AM, the distortion increases appreciably as a result of nonlinearity of the screen grid modulation characteristic of the output tube (V103) and the diode circuit associated with the metering and AGC circuitry.



A - WITH CONSTANT AMPLITUDE SIGNAL
B - HOLDING CONSTANT PERCENT AM INDICATION

Figure 25. AM Fidelity Curve

Figure 25 shows a typical 202H AM Fidelity Curve. The AM response, has a slight rise near 100 kc similar to the FM response.

The AM response for a constant input level modulating signal also has a slight rise as the modulation frequency decreases below 100 cps (Fig. 25A). This is caused by the AGC circuit passing some of the demodulated signal and applying it to the RF Unit output stage screen grid in near quadrature to the normally applied AM signal. The vector addition of these two components produces a resultant signal which is slightly larger than the normal input signal. This appears as a slight increase in AM as modulation frequency decreases. The AM meter has a flat response down to 10 cps and therefore, it is possible to hold a constant percentage modulation down to 10 cps by adjusting the modulating signal to give a constant meter indication. Fig. 25B shows the condition.

The specification for Amplitude Modulation accuracy is $\pm 10\%$ of the desired modulation at 30% and 50% modulation at 400 cps modulating frequency. An oscilloscope display of the AM trapezoid will aid in setting modulation to desired levels if closer tolerances are required. Trapezoidal presentation of AM is discussed in Section VI—Maintenance.

WAVEFORM, RF CARRIER

The 202H employs an RF oscillator which always operates at a subharmonic of the desired output frequency, (f). On the low band (54-108 mc), with one doubler stage in operation, the oscillator operates at one-half of the output frequency. On the high band

(108-216 mc), with both doublers operating, the oscillator frequency is one-fourth of the output frequency. Spurious outputs then, are likely at sub-harmonics and non-integral harmonics of the output frequency as well as the customary integral harmonics. Spurious output of integral harmonics is difficult to detect visually because it distorts each cycle of the output in exactly the same way. Spurious outputs of sub-harmonics and non-integral harmonics can, however, distort by alternately compressing and peaking successive cycles.

Fig. 26 shows a typical waveform displayed on a wideband oscilloscope from a 202H operating at 54 mc. The subharmonic $f/2$ was measured to be 33 db below and the non-integral harmonic $3f/2$ was 36 db below the fundamental, using a narrow band receiver. The 202H specifications guarantee that all spurious RF output voltages will be at least 30 db below the desired fundamental output frequency.

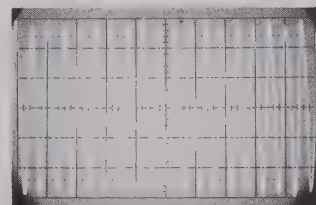


Figure 26. 202H RF Waveform

SECTION VI MAINTENANCE

GENERAL

The 202H is a complex FM-AM Signal Generator; however, with its straight forward design, the instrument can be readily maintained and repaired in the field. With the exception of the RF Unit, all parts are accessible by removal of the top, side, and bottom covers. The RF Unit may be readily removed from the instrument for maintenance or repair. In some cases removal of the RF Unit cover will provide sufficient accessibility.

PREVENTATIVE MAINTENANCE

Ventilation

The 202H utilizes convection and conduction cooled semiconductors in the power supply, thus eliminating the need for a blower. The cabinet is adequately ventilated to disperse the heat generated within the instrument. Operating the instrument with the vents blocked will not only shorten tube and component life, but will require a much longer warmup time for frequency stabilization.

Lubrication

The 202H is adequately lubricated for the life of the instrument. The only necessity for added lubrication is for the lubricants wiped off during replacement of parts. Excessive lubrication can be damaging to contacts in electronic devices and should be avoided. To lubricate shafts, gears, bushings, etc. in the 202H the following lubricant is recommended: Beacon No. 325 manufactured by Humble Oil & Refining Co.

Semiconductor Insulators

In some cases the semiconductors; i.e., transistors and diodes, are insulated electrically from the chassis or heat sink by material such as mica. For

maximum transfer of heat to the chassis through the insulator, it is coated on both sides before assembly with silicone grease DC-4 manufactured by Dow Corning Corporation.

TROUBLE SHOOTING AND REPAIR

Tube and Transistor Replacement Guide

The Tube and Transistor Replacement Guide is primarily a checklist to show tube and transistor functions with the readjustments required after tube or transistor replacement. The "Symptoms Noted" information, like the Trouble Shooting Chart, is included as an organized starting point in the event that the instrument is not performing properly.

To gain access to the tubes and transistors, the following disassembly procedures must be used:

1. Removal of the top cover of the 202H will allow changing of tubes V300, V500, V501, V502, V600, V601, and V602.
2. Removal of the top cover and RF Unit cover will allow changing of tubes V100, V101, V102, and V103.
3. Removal of the top cover and disassembly of terminal board 307700 from mounting brackets allows changing of transistors Q202, Q203, and Q204.

4. Removal of the bottom cover of the 202H will allow changing of tube V400.

5. Removal of the top, bottom, and right side covers will allow changing of transistor Q201.

6. Removal of the top, bottom, and left side covers will allow changing of transistor Q200.

Trouble Shooting Chart

The Trouble Shooting Chart lists symptoms that could possibly develop in the instrument and details faults, probable causes of these faults, remedies, and procedures for correcting these conditions. It is suggested that this chart be used as a first step in analyzing trouble since considerable time and effort associated with unnecessary readjustment or alignment can therefore be avoided.

Voltage and Resistance Chart

The Voltage and Resistance Chart indicates normal operating conditions for the 202H with no external equipment attached. Voltages were checked with a VTVM (hp 410B). Resistance readings were made under the same conditions with power disconnected. Some resistance readings have been omitted as the readings have no significance; i.e., cases where electrolytic capacitors or semiconductor devices are connected in the circuit.

TUBE AND TRANSISTOR REPLACEMENT GUIDE

Reference Symbol	Type	Application	Readjustment Required	Symptoms Noted
V100	6688	Reactance Modulator	Bias Adj. (R107) and Frequency calibration check	No frequency modulation
V101	6AF4	RF Oscillator	Frequency calibration check	No RF
V102	6688	1st Doubler	Doubler tracking check	Weak or no RF
V103	6688	2nd Doubler	Doubler tracking check	Weak or no RF, No AM
Q200	2N1136	DC Fil Reg.	None	
Q201	2N1533	B Supply Reg.	Reg. Input Adj. (R201)	Low or no dc voltage
Q202	2N1379	Reg Driver Amp.	None	Poor regulation—low dc voltage
Q203	2N1379	Reg Amplifier	R207	Poor regulation
Q204	2N1379	Reg Amplifier	R207	Poor regulation
V300	6AW8A	AGC dc Amplifier	AGC Bias Adj. (R308) (R313)	Automatic RF level set not functioning properly
V400	6BK7B	FM Cathode Follower	R416	No frequency modulation internal or external (Modulation meter indicates).
V500	6AU6A	Audio Oscillator	Osc. Gain Adj. (R510)	No internal modulation
V501	6AQ5A	Audio Oscillator Output	Osc. Gain Adj. (R510)	No internal modulation
V502	6AW8A	Amplifier (Dual)	None	No amplitude modulation
V600	6AU6A	Meter Amplifier	(R721) Mod Meter Adj. (R612)	No Modulation Meter indication
V601	6AU6A	Meter Amplifier	Mod Meter Adj. (R612) (R721)	No Modulation Meter indication
V602	6DJ8	Mod Meter Cathode Follower	None	No Modulation Meter indication

TROUBLE SHOOTING CHART

SYMPTOM	PROBABLE CAUSE	LOCALIZING AND REMEDYING FAULT
1. No RF output No RF Monitor Meter indication.	Defect in RF Unit.	Check voltages at J101 receptacle for RF Unit supply voltages. No voltage at pin #3 could indicate an open fuse in the dc filament line. Check fuse F201 on the back panel of the 202H. Next, remove RF Unit cover. (See Disassembly Procedure). Check voltages at RF filter and then proceed to the tube sockets. (See Voltage and Resistance Chart.)
2. No RF output RF Monitor Meter indicates output.	Defective Attenuator resistor.	Check dc resistance at RF output jack (J100). It should be approximately 50 ohms. A momentary connection to external high power source could cause the series resistor R117 in the attenuator to open. Replacement will require physical realignment of attenuator coil and recalibration of piston attenuator. (See Alignment and Adjustment Procedures.)
3. No RF output indicated on RF Monitor Meter.	Defect in meter circuitry.	Check for AM on Modulation Meter. No AM indicates defective diode (CR101), open capacitor (C121), or shorted capacitors in RF Filter. (No output from detector circuit makes AGC system inoperative and will result in excessive RF output.) Also check for dc potential at Monitor Meter.
4. Weak RF as indicated by RF Monitor Meter.	Low B + supply.	Check power supply output voltage. Referring to Fig. 27 check B+ to chassis to B- voltage relationship. It can be seen from the basic circuitry that filament to cathode shorts in tubes such as V300, V600, and V601, can change the B+ to ground circuit balance. It is important that the described relationship be maintained. Note: It is suggested that when a high resistance short exists in the 202H, the power plug P101 from the RF Unit be removed to help isolate the defect.
5. No FM deviation A. No FM deviation internal or external as indicated in output of 202H. B. No FM deviation from internal oscillator. Meter indicates deviation. C. No FM deviation from external modulating source. Meter indicates deviation.	Defective Reactance Modulator (V100). Defective FM Cathode Follower (V400B). Defective FM Cathode Follower (V400A).	Check for proper operating voltages on tube. See Voltage and Resistance Chart. Check for proper operating voltages on tube. See Voltage and Resistance Chart. Check for proper operating voltages on tube. See Voltage and Resistance Chart.
6. No AM, internal or external as indicated on Modulation Meter.	Defective Amplifier (V502). Defective J500 Ext Pulse Jack. Defect in Modulation Meter circuitry.	Externally, the output of the Amplifier can be checked at J500 Ext Pulse Jack by using a phone plug on an oscilloscope lead and inserting lightly into jack to make connection, without opening jack contacts. (There is approximately 45 vdc at this point, so necessary precautions must be observed.) Check for dc potential on pin #4 of J101. Poor contacts on J500 opens screen grid circuit of V103. This situation is also indicated by weak RF. See Symptom #3. It should be noted that the RF Monitor Meter does not indicate in either AM or FM when this problem exists.
7. No Internal modulation, AM or FM.	Defective audio oscillator.	Check plate (pin #5) of V501 with scope for audio oscillator output. If no output, check resistance lamp RT500 in cathode of V500. Check operating voltages on V500 and V501. See Voltage and Resistance Chart. Note: If RT500 is changed the Osc Gain Adj (R510) will require checking. (See Adjustment and Calibration.) Externally the audio oscillator output can be checked on the FM Ext Osc posts with the INT MOD switch in the FM position.
8. Insufficient AM	Weak output from internal audio oscillator.	Check Osc Gain Adj (R510). Change resistance lamp RT500 in cathode of V500 and recheck output. (See note above.)
9. Intermittent RF	Internal plugs loose in sockets.	Check P101 and P102 for proper seating in receptacles J101 and J102.
10. Microphonism	RF Unit not floating free.	Check to assure shipping devices for securing RF Unit have been loosened or removed. (See Installation.)
11. Automatic level set does not hold meter red line for the range of the instrument.	Defective AGC Amplifier circuitry.	Check for proper operating voltages on V300. It should be noted that the RF Unit is operating as RF Monitor Meter indicates; however, the circuitry in the RF Unit which is associated with the AGC amplifier can also be at fault. (See Symptom 3.)

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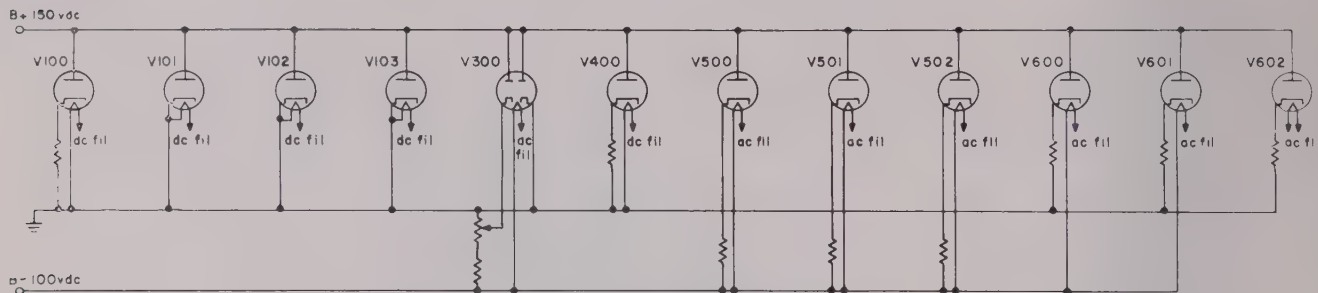
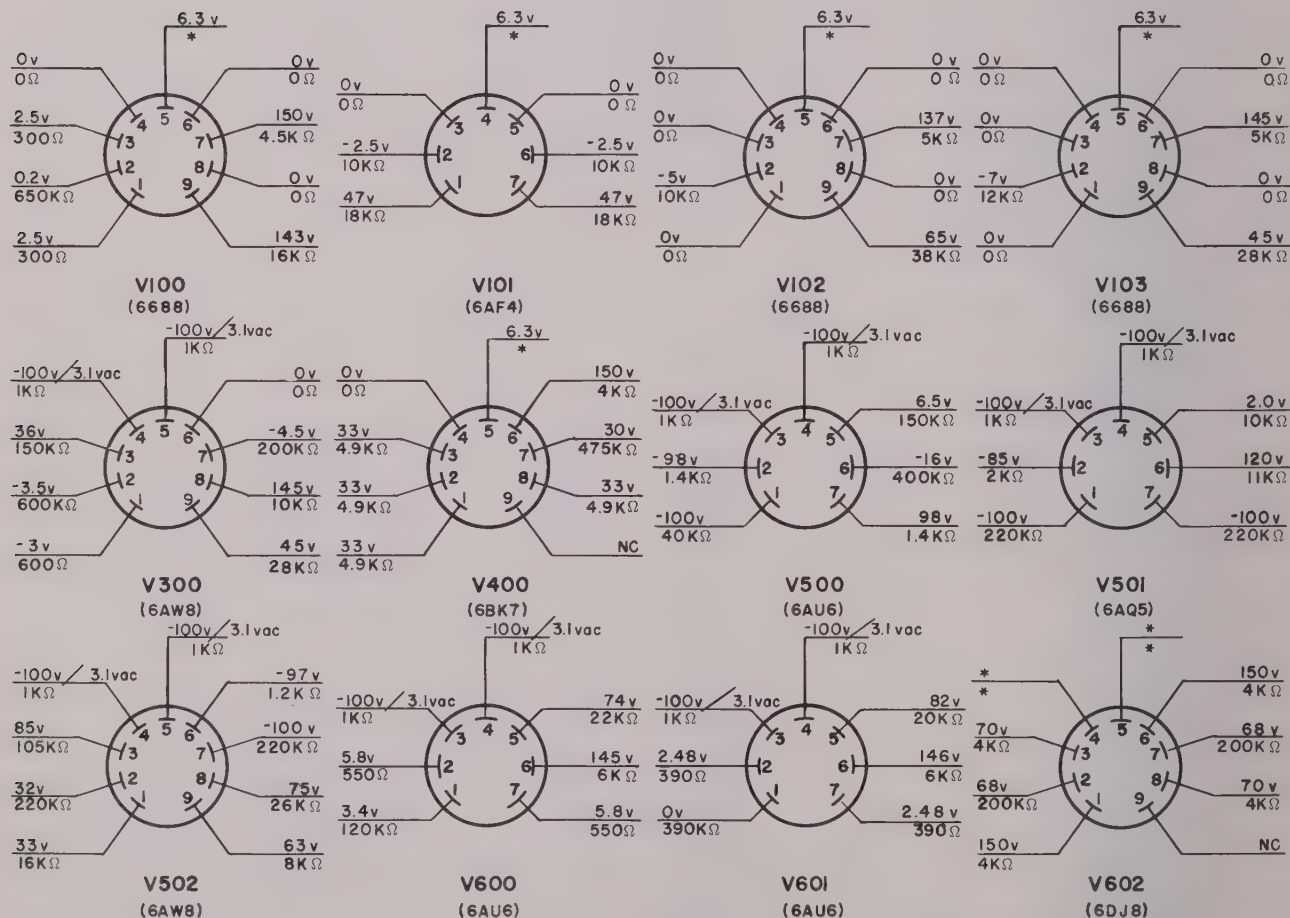
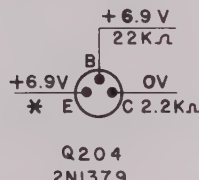
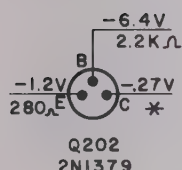
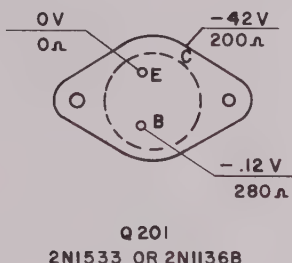
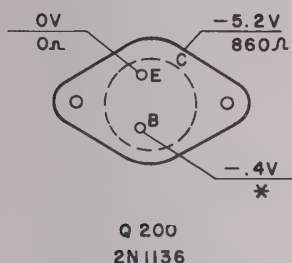


Figure 27. Basic Circuit 202H Power Distribution System



* NOT SIGNIFICANT

VOLTAGE AND RESISTANCE CHART — TUBES



VOLTAGE AND RESISTANCE CHART — TRANSISTORS

MECHANICAL DISASSEMBLY PROCEDURES

Top and Bottom Covers

1. Remove four screws.
2. Slide cover toward rear of instrument to disengage rear foldover of cover.

Right and Left Side Covers

1. Remove top and bottom covers (See above).

2. Remove four machine screws and nuts securing side covers to instrument.

RF Unit Cover

1. Remove three tierod nuts and washers.
2. Loosen screws securing the RF Unit end plate.
3. Slide end plate toward rear of instrument to disengage screws from slots.
4. Grasp cover and slide it toward rear of instrument with as little tilting motion as possible. It is imperative that the cover retain its original shape so as to fit securely back in place on the RF Unit housing. A bent or damaged edge on the cover will allow a small amount of RF leakage beyond the very low original limit (See RF Unit—Reinstallation-item 3).

RF Filter

1. Carefully remove RF Unit cover (See above).
2. Disconnect plugs P101 and P102 from main chassis.
3. Remove cable clamp on RF Unit housing.
4. Unsolder leads connected to filter.

5. Loosen large nut securing the RF Filter.

6. Slide RF Filter out of RF Unit housing.

At this point the RF Filter is available for maintenance and repair. For replacement of the complete assembly, the plugs (P101 and P102) must be removed from the cables.

RF Unit

1. Disconnect P101 and P102 plugs from main chassis.
2. Rotate frequency control shaft until set screws in coupling are accessible and remove two set screws from coupling on end toward front of instrument. The coupling can remain attached to the RF Unit.

NOTE: The frequency dial setting should be noted at this point to aid in the reassembly of the RF Unit.

CAUTION: There is no stop on the RF Unit frequency control shaft. Rotating the frequency control shaft with the RF Unit out of the instrument, will cause the gear on the frequency control shaft to disengage from the split gear on the rotor shaft. See Mechanical Disassembly Procedure—RF Unit Frequency Control Shaft for engagement procedure.

3. Rotate attenuator control to stop with attenuator piston completely into the tube. Note dial setting (dial setting vs attenuator stop) to aid in the reassembly of the RF Unit. Back off attenuator control to make set screws

accessible. Remove two set screws from coupling at end toward rear of instrument. The coupling will remain attached to the front panel shaft.

4. Turn RF range switch to "OFF" Loosen set screws in coupling at the gear box end of coupling. Coupling will remain with RF Unit.

When reassembling the RF Unit, the coupling connection should be in the same position as it was originally. To test switch coupling position turn 202H ON and assure the RF Monitor Meter reads zero in the OFF position of the Range Switch.

5. Remove RF Output jack from front panel of 202H.

6. Disconnect ground strap from base of shock mount.

7. Remove four screws securing RF Unit brackets to shock mounts.

8. Left out RF Unit complete with brackets and cables.

Before re-installing the RF Unit in the 202H, the following checks should be made to insure against excessive RF leakage:

1. The RF filter should be secured with the grounding washer in place. The large hex nut should be tight.
2. The attenuator should be fastened securely by the four mounting screws.
3. The RF Unit cover should be of proper rim size to fit tightly into the RF Unit casting. At the factory, the cover is placed on a sizing jig (Fig. 28) before assembly to the RF Unit to insure proper size and roundness of the rim.

After the RF Unit is replaced, the 202J will require a frequency calibration and attenuator calibration check.

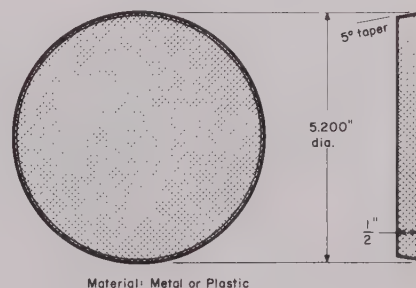


Figure 28. RF Unit Cover Sizing Jig

Piston Attenuator

The Piston Attenuator assembly may be removed completely from the RF Unit, but this procedure is not recommended. For repairs such as resistor re-

placement, if disassembly is required, the piston only should be removed from the tube. The piston is removed as follows:

1. Referring to Fig. 66, the collars, gears, and stop plate on shaft (307935) are loosened to allow removal of the shaft. Make note of order of parts on shaft for reassembly purposes.
2. Remove three screws from piston bushing.
3. Slide piston out of attenuator.

During reassembly, the tension on the spring loaded gears will have to be adjusted. This is accomplished, after shaft parts are secured, as follows:

1. Attach a front panel knob directly to the attenuator shaft (for check purposes only).
2. Collar (307995) is loosened and rotated until springs are tight but not under tension. Secure collar.
3. Oscillate knob. Check for looseness in gears as detected by feel during knob rotation.
4. Loosen and rotate collar (307995) to increase tension on spring. Secure collar and recheck for looseness.
5. Repeat step 4 until looseness just disappears. Too much tension will show up as drag or stiffness of attenuator control. This in turn will make small incremental setting of the control difficult.

Terminal Board (BRC Part No. 307700)

This terminal board mounts three transistors and must be disassembled from its brackets to gain access to the transistors for replacement.

1. Remove four machine screws with lockwashers from corners of the terminal board.
2. If necessary, the terminal board assembly can be completely removed from the 202H by unsoldering five leads.

RF Monitor Meter

1. Remove two nuts securing lugs to meter connections.
2. Remove four nuts securing meter corners. Access holes are provided in the instrument framework.
3. Slide meter out of front panel.

Modulation Meter

1. Remove two nuts securing lugs to meter connections.
2. Remove four nuts securing meter corners. Access holes are provided in the instrument framework.

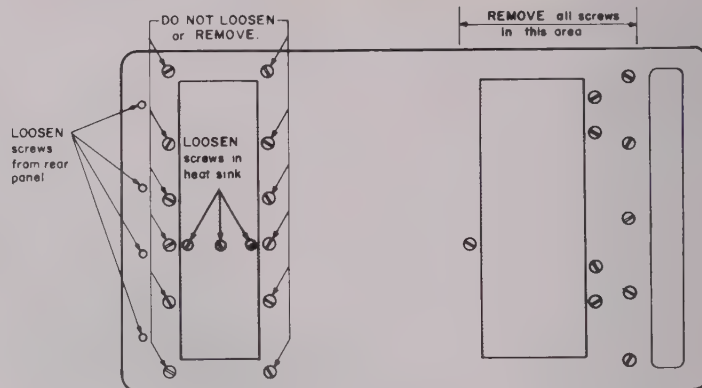


Figure 29. 202J Side View - Front Panel Removal

3. Slide meter movement out of front panel.

Front Panel Assembly

Several components can be replaced only after moving the front panel. This procedure gives the method required to gain access to these parts.

1. Remove the following control knobs:
 - a. VERNIER (5A)
 - b. FREQUENCY MEGACYCLES (4A)
 - c. ΔF KC (19A)
 - d. ΔF KC LOCK (19B)
 - e. MICROVOLTS DBM (8A)
 - f. RF Range (20)
2. Remove the top and bottom covers.
3. Remove adhesive backed trim strips (308137-51) on either side of the 202H.
4. Remove or loosen screws as indicated in Fig. 29. This should be done on both sides of the instrument.
5. Spring side castings away from front panel to disengage front panel from tabs at top and bottom of side castings. Spring one side at a time, moving front panel about an inch forward.
6. Tilt front panel forward with care to avoid damage to components, wires and cables. In this position all repairs can be done.

Gear Assembly

It is not recommended that the gear assembly be repaired in the field. Referring to Fig. 67, the gear assembly (307792-2) is replaced as a unit. To remove this assembly use the following procedure.

1. Remove the following control knobs:
 - a. VERNIER (5A)
 - b. FREQUENCY MEGACYCLES (4A)
 - c. ΔF KC (19A)
 - d. ΔF KC LOCK (19B)

2. Remove top and bottom covers.
3. Remove RF Unit, but do not remove RF Unit cover. (See RF Unit disassembly.)
4. Remove nut and machine screw at bottom edge of gear assembly.
5. Remove screw and lock washer from either end of gear assembly angle bracket (along front top edge of 202H).
6. Remove gear assembly angle bracket. Fiducials and scale masks remain attached to this bracket.
7. Remove ΔF KC control (R410) by disassembling the dial scale and lock assembly. Use open-end wrench to remove nut securing R410 to gear assembly rear plate.
8. Remove gear assembly and dial scales from 202H.
9. Dial scales may be removed for replacement of gear assembly.

NOTE: Do not disassemble gear mechanism.

RF Unit Rotor Assembly

1. Remove RF Unit from 202H.
2. Remove attenuator assembly.
3. Remove RF Unit housing.
4. Remove rotor shaft wiper from top of shaft in 2nd Doubler compartment.
5. Loosen rotor shaft wipers in 1st Doubler and Oscillator compartments.
6. Loosen nut securing end bearing at rear of RF Unit.
7. Loosen end bearing while holding rotor shaft.
8. Lift out rotor assembly.

NOTE: The ends of the rotor assembly shaft rest against pyrex ball bearings which will drop out during disassembly.

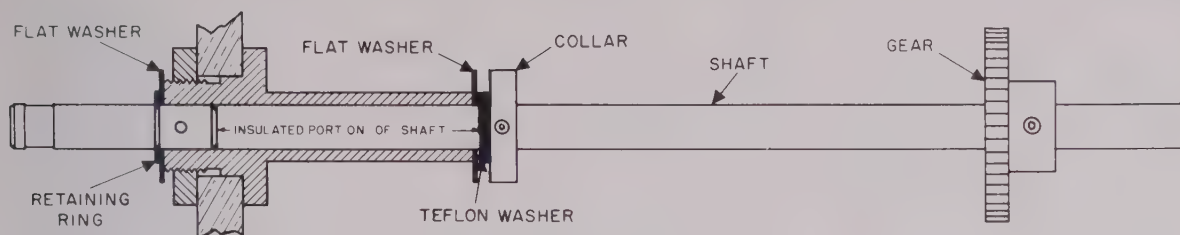


Figure 30. RF Unit Frequency Control Shaft

When reassembling the rotor shaft, the adjustment on the end bearing should be done with extreme care. The end bearing adjustment should just eliminate any end play. It should allow free rotation of the rotor such that the starting torque required to rotate the frequency shaft at the front of the RF Unit should not exceed 6 inch ounces.

RF Unit Stator Assembly

1. Remove RF Unit from 202H.
2. Remove RF Unit Rotor Assembly from RF Unit.
3. Remove two machine screws securing the stator base.
4. Lift out stator assembly.

NOTE: When replacing the stator assembly it should be noted that, in full mesh condition, the stator and rotor plates edges should be in mechanical alignment. Shims are used between stator plate assembly and insulator base to insure mechanical lineup.

RF Unit Frequency Control Shaft (Fig. 30)

1. Remove RF Unit from 202H.
2. Loosen setscrews in gear and in collar.
3. Remove "C" washer from shaft at front of RF Unit.
4. To remove shaft, slide shaft toward rear of RF Unit.

When reassembling frequency control shaft, the split gears will have to be spring loaded properly as follows:

1. With split-gear assembly disengaged from the gear on the frequency control shaft, rotate one gear with respect to the other to take up slack in spring.
2. After spring is tight, but not under tension, rotate one gear approximately $2\frac{1}{2}$ to 3 teeth with respect to the other.
3. Holding tension on split gears, rotate the split gear assembly until it engages in the gear on the frequency control shaft. In this condition, the load-

ing on the springs should be correct as to meet the requirement for torque on frequency control shaft described under Mechanical Disassembly Procedure—RF Unit Rotor Assembly.

PISTON ATTENUATOR RESISTOR REPLACEMENT (Fig. 31)

The proper installation of resistors in the piston attenuator is a very critical operation. This careful procedure is necessary to maintain the low VSWR specified for the attenuator.

1. Remove RF Unit from 202H. See Mechanical Disassembly Procedures—RF Unit.
2. Remove Attenuator piston assembly. See Mechanical Disassembly Procedures—Piston Attenuator.
3. Remove three screws in rack assembly.
4. Slide rack assembly away from pick-up loop as far as possible.

To avoid overheating the coax cable insulation and the tape around the "cup" of R118, both the cable and R118 must be removed before attempting to unsolder the grounded end of R117.

5. Unsolder coax center conductor from

pick-up loop.

6. Remove nut at cable end of piston and withdraw coax cable.

7. Unsolder pick-up loop from R117 and remove pick-up loop together with R118 complete with insulating tape.

This tape is the dielectric for the special capacitor shown on the schematic as C147.)

8. Apply soldering iron to outside of piston at grounded end of R117. Use only enough heat to loosen and remove R117. **DO NOT OVERHEAT.**

9. Clean hole and insert resistor, R117.
10. Resolder and smooth outside of assembly to assure proper fit when rack is repositioned.

11. Check insulation around "cup". It should be one layer of No. 33 electrical tape (adhesive side against "cup").

12. Insert R118 in place with the resistor end flush with the attenuator face. This should be a "snug" fit.

13. Reinsert coax cable and tighten nut.

14. Resolder center conductor of coax cable to junction of pick-up loop and R118 as shown in Fig. 31.

15. Resolder pick-up loop and R118

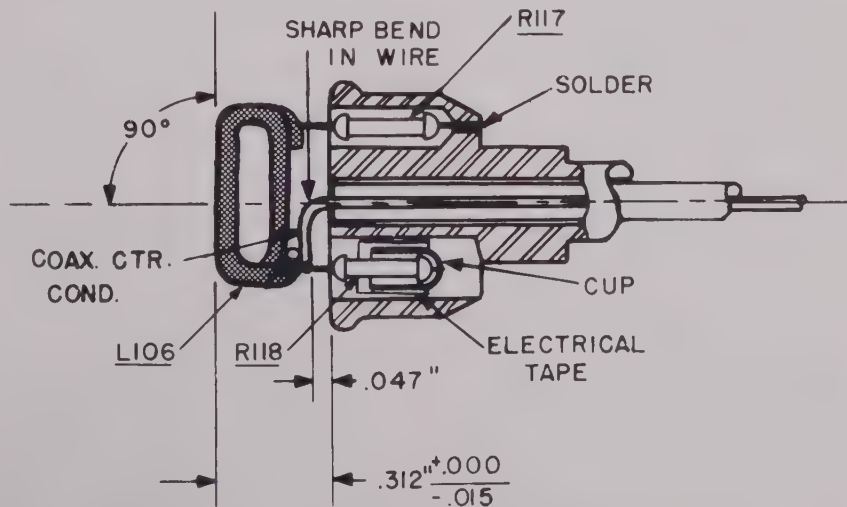


Figure 31. Piston Attenuator Resistor Replacement

as shown in Fig. 31.

16. Reassemble Piston Attenuator.

17. Reassemble RF Unit into 202H.

18. After reassembly the RF Monitor calibration will have to be checked. As a result of removing the RF Unit the frequency dial calibration will also have to be checked.

SPECIAL INSTRUCTIONS FOR TRANSISTORS AND DIODES

Semiconductors can be damaged by excess heat such as might be imposed by a soldering iron. When replacing transistors and diodes, always hold wire between semiconductor and terminal with a pair of long-nose pliers while soldering to help to dissipate some of the heat. When this practice cannot be followed, avoid long exposure to heat from the soldering iron. Use a low wattage iron.

Q200

This transistor is mounted with the collector insulated from chassis ground by means of a mica insulator and transistor socket or shoulder washers on screws. See special instructions under Preventative Maintenance - Semiconductor Insulators.

Q201

This transistor is mounted with the collector insulated from chassis ground by means of a mica insulator and transistor socket or shoulder washers on screws. One mounting screw on this transistor is isolated from the transistor where the transistor socket is not used. Check before disassembly to avoid incorrect replacement procedure. See special instructions under Preventative Maintenance-Semiconductor Insulators.

Q202, Q203, and Q204

These transistors are soldered in. Remove terminal board (307700) when replacing transistor.

CR100, CR200, CR201, CR202, CR203, CR206, CR207, CR210, CR211, CR212, CR213, CR300, CR301, CR302, CR303, CR304, CR601, CR602

These diodes are soldered in. Observe polarity before replacement.

CR101

This diode fits into a clip. Observe polarity before replacement.

CR204, CR205, CR208, CR209, CR400

These diodes are mounted to a heat sink. In some cases mica insulators are

used to electrically isolate the diode from chassis ground. See special instructions under Preventative Maintenance-Semiconductor Insulators.

ADJUSTMENT AND CALIBRATION

Any tolerances listed in this section are the limits indicated by the Specifications in Section II. Factory adjustments are made to considerably closer tolerances corresponding to standard practice in the industry. Field adjustments to closer than specified tolerances are possible if time and patience are used.

Recommended Equipment List

The following instruments are recommended for use in the adjustment and calibration of the 202J. Pertinent information is given for substitution purposes.

1. hp 412A dc VTVM

Range: 1 mv to 1000 v (full range not required).

Accuracy: $\pm 1\%$ full scale.

2. hp 400H ac VTVM

Range: 1.0 mv to 300 v.

Frequency Range: 10 cps to 4 mc.

Accuracy: $\pm 1\%$ 5 cps to 500 kc.
 $\pm 5\%$ 10 cps to 4 mc

3. hp 330B Distortion Analyzer

Frequency Distortion Range: 20 cps to 20 kc.

Accuracy: $\pm 3\%$.

Input Level: At least 1 v rms

4. hp 5243L Electronic Counter

Frequency Range: 0 cps to 20 mc.

5. hp 5251A Frequency Converter

Use with hp 5243L Electronic Counter for frequency range to 20 to 100 mc.

6. hp 5253A Frequency Converter

Use with hp 5243L Electronic Counter for frequency range of 100 mc to 512 mc.

7. High Output Audio Oscillator

Capable of 50 v (into 6000 ohms) output over audio range.

Frequency Range: 20 cps to 20 kc.

Accuracy: $\pm 1\%$.

8. hp 540B Transfer Oscillator

Frequency Range: 10 mc to 12.4 K mc.
Type of Input Signal: CW, AM, FM, or Pulse.

9. hp 130C Oscilloscope

Sensitivity: 0.2 mv/cm.

Frequency Range: 0 to 500 kc.

10. Signal Generator with same RF frequency range as 202H

11. hp 431A Power Meter

Power Range: 10 μ w to 10 mw.
Accuracy: $\pm 3\%$ of full scale.

12. hp 478 Thermistor Mount for use with hp 431A Power Meter

13. hp 400D VTVM

Used in the linearity measurement set-up. For this application a slight modification is made during use (See Fig. 36).

14. hp 650A Test Oscillator

Frequency Range: 10 cps to 10 mc.

Accuracy: $\pm 2\%$ to 100 kc, $\pm 3\%$ 100 kc to 10 mc.

Output: .015 watts into 600 Ω (Approximately 3v).

15. hp 466A ac Amplifier

Frequency Response: ± 5 db 10 cps to 1 mc.

Gain: 20 db or 40 db at 1 kc.

Distortion: $< 1\%$ 10 cps to 100 kc.

Output: 50 Ω in series with 100 μ f.

16. Voltage Calibrator

Range: 0-10 v rms.

Frequency: 1000 cps.

Accuracy: $\pm 0.5\%$.

Power Supply

EQUIPMENT REQUIRED

1. hp 412A dc VTVM or equivalent.*
2. hp 400H dc VTVM or equivalent.*
3. Variable 60-cycle power source with meter.

B+ SUPPLY

Preliminary Setup

1. INT MOD switch in "OFF" position.

2. RF METER ADJ (R300) and MOD METER ADJ (R612) to full counter-clockwise position.

3. AC VTVM and dc VTVM connected across output filter capacitor (C202).

Adjustment

1. With 115 vac input to 202H, adjust R207 for 150 vdc ± 0.5 v as read on dc VTVM. Vary input voltage to 202H from 105 to 125 vac. DC output should not vary more than ± 0.5 vdc.

2. With 104 vac input to 202H, adjust Ref Input Adj (R201) for maximum resistance without introducing ripple on B+. Use ac VTVM or oscilloscope to observe ripple.

3. Check ripple over 105 to 125 vac input range. Voltmeter reading of ripple

*See Recommended Equipment List under Adjustment and Calibration.

must not exceed .00177 vac. (When checked with oscilloscope, ripple must not exceed .005 peak-to-peak.)

DC FILAMENT SUPPLY CHECK

1. With 115 vac input to 202H, the dc filament voltage at pin 3 of J101 should be 7.3 ± 0.5 v.

2. When varying input voltage from 105 to 125 vac, the dc filament voltage should not vary more than 0.15 v.

3. Using an oscilloscope, check ripple over 105 to 125 vac input range. The ripple must not exceed 0.2 v peak-to-peak.

Modulation Oscillator

EQUIPMENT REQUIRED

1. hp 400H ac VTVM or equivalent.*
2. hp 330B Distortion Analyzer or equivalent.*
3. hp 5243L Electronic Counter or Equivalent.*

GAIN ADJUSTMENT

Preliminary Setup

1. INT MOD Switch—AM
2. FREQ CPS—400
3. AM Control—fully clockwise.
4. ac VTVM connected across AM EXT OSC terminals.

Adjustment

1. Adjust R510 (OSC GAIN ADJUST) for 26.0 v rms at AM terminals.
2. Voltages at all positions of FREQ CPS switch should be $26.0 \text{ v} \pm 2.5 \text{ v rms}$.

DISTORTION CHECK

Preliminary Setup

1. INT MOD switch—FM
2. FREQ CPS switch—400.
3. FM Control—fully clockwise.
4. Connect distortion analyzer to FM EXT OSC terminals.

Measurement

Distortion should be less than 0.50%.

NOTE: If distortion is too high, change audio oscillator output tube V501 or oscillator cathode bias lamp (RT 500). If tube or lamp is changed, repeat gain adjustment of Modulation Oscillator.

OSCILLATOR FREQUENCY CHECK

Preliminary Setup

1. INT MOD switch—FM.
2. FREQ CPS switch—all frequencies.

3. Attach Electronic Counter to FM terminals.

Measurement

Check each frequency of the internal modulation oscillator. Frequencies should be within $\pm 5\%$.

Modulation Meter Circuitry

EQUIPMENT REQUIRED

1. hp 400H ac VTVM or equivalent.*
2. hp 650A Test Oscillator or equivalent.*
3. Voltage Calibrator.*

MODULATION METER CHECK — FM

Preliminary Setup

1. INT MOD switch—OFF.
2. MOD METER switch—FM.
3. DEV KC—7.5.
4. FM control—Maximum counter-clockwise.

Check

Check MODULATION meter for electrical zero.

RANGE RATIOS

Preliminary Setup

1. MOD METER switch—FM.
2. DEV KC—250.
3. INT MOD switch—FM.
4. RF range switch—108-216 mc.
5. Attach Voltage Calibrator to FM EXT OSC terminals.
6. Set Voltage Calibrator for 1000 cycles with an output of 0.500 v rms.

Calibration and Check

1. Adjust FM control to 250 kc full scale on Modulation Meter.
2. Change DEV KC switch to 75 kc. Change Voltage Calibrator output to read full scale on Modulation Meter. The Voltage Calibrator reading should be nominally 0.15 v rms.
3. Change DEV KC switch to 25 kc. Change Voltage Calibrator output to read full scale on Modulation Meter. The Voltage Calibrator reading should be nominally 0.050 v rms.
4. Change DEV KC switch to 15 kc. Change Voltage Calibrator output to read full scale on Modulation Meter. The Voltage Calibrator reading should be nominally 0.15 v rms.
5. Change RF range switch to 54-108 mc. Change DEV KC switch to 250 kc. Change Voltage Calibrator output to read full scale on the Modulation Meter. The Voltage Calibrator reading should

be nominally 1.00 v rms.

MODULATION METER LINEARITY CHECK

Preliminary Setup

1. MOD METER switch—FM.
2. INT MOD switch—OFF.
3. DEV KC switch—7.5.
4. Attach Voltage Calibrator to FM EXT OSC terminals.
5. Set Voltage Calibrator output to 4.0 v rms at 1000 cps.
6. Adjust FM control for 60 kc reading on Modulation Meter.

Linearity Check

1. Using the controls on the Voltage Calibrator, change the output until the MODULATION Meter reads, 75 kc. The Voltage Calibrator reading should be 5.000 v rms.
2. Reduce the Voltage Calibrator output until the MODULATION Meter reads 45 kc. The Voltage Calibrator reading should be 3.000 v rms.
3. Reduce the Voltage Calibrator output until the MODULATION Meter reads 30 kc. The Voltage Calibrator reading should be 2.000 v rms.

MODULATION METER FREQUENCY RESPONSE

Preliminary Setup

1. INT MOD switch—OFF.
2. MOD METER switch—FM.
3. DEV KC switch—250.
4. Attach test oscillator and ac VTVM to FM EXT OSC terminals.
5. Set test oscillator output to 3.0 v rms at 400 cps.
6. Adjust FM control for full scale reading on MODULATION meter.

Frequency Response Check

1. Change frequency of test oscillator from 400 cps to 30 cps. Readjust control on test oscillator for full scale reading on the MODULATION Meter. The VTVM reading should be nominally 3.00 v rms.
2. Change frequency of test oscillator from 30 cps to 100 kc. Readjust control on test oscillator for full scale reading on MODULATION Meter. The VTVM reading should be nominally 3.00 v rms.
3. Change frequency of test oscillator from 100 kc to 200 kc. Readjust control on test oscillator for full scale reading on MODULATION Meter. The

*See Recommended Equipment List under Adjustment and Calibration.

VTVM reading should be nominally 3.00 v rms.

RF Alignment

The following information is for the complete factory alignment of a new instrument. During maintenance or repair of an instrument, a certain amount of realignment might be required. It is important that only areas affected by repair should be aligned. Thus, only the part of the procedure pertinent to the instrument being serviced should be used.

Tube replacement will necessitate dial slipping and/or trimmer adjustment **ONLY**.

EQUIPMENT REQUIRED

1. hp 5243L Electronic Counter and 5253A or 5251A Converter or equivalent.*
2. hp 130C Oscilloscope or equivalent.*
3. Oscilloscope Probe with 150 K ohm resistor in series.
4. hp 431A Power Meter or equivalent.*
5. Extension Cable for J101 to P101 (approximately 2 feet long).
6. Extension Cable for J102 to P102 (approximately 2 feet long).
7. Tuning Dial (BRC No. 20209).

The first part of the alignment procedure is performed with the RF Unit out of the 202H cabinet. This portion of the alignment will only be required if major repairs are performed on the RF Unit. Touch-up and final alignment are done with the RF Unit in place.

OSCILLATOR ALIGNMENT

Preliminary Setup

With the RF Unit removed from the 202H and the cover off, reconnect P101 and P102 plugs to the main chassis. Additional extension cables may be used for convenience. Turn the 202H power on. Attach tuning dial (BRC No. 20209) to shaft. Attach indicator to RF Unit housing. Align dial so "O" coincides with full mesh of oscillator rotor plates. Set ΔF KC control to zero (arrow on knob pointing up). Trimmer capacitors C108, C116, and C122 should be set to mid-capacitance. Attach frequency counter with appropriate converter to RF output jack. Turn attenuator to maximum output.

*See Recommended Equipment List under Adjustment and Calibration.

Alignment

1. Set dial to 54 mc. Adjust coil T100 until counter reads 54 mc $\pm 0.5\%$.*

NOTE: If oscillator frequency is low, decrease inductance by spreading windings on coil. If frequency is high, increase inductance by moving windings closer together.

2. Set dial to 108 mc. Adjust trimmer C108 until counter reads 108 mc $\pm 0.5\%$.
3. Recheck frequency calibration at 54 mc. Adjust coil T100 if necessary.**
4. Reset dial to 108 mc and check calibration. Adjust trimmer C108 if necessary.
5. Change dial to 100 mc.**

It will be noted that the end plates of the rotor section of the ganged variable capacitor are segmented. These small sections are used for tracking across the band at 10 mc increments. The rotor plate just going into mesh is adjusted to give a reading of 100 mc $\pm 0.5\%$ on the counter. To lower frequency, decrease plate spacing. To raise frequency, increase plate spacing.

NOTE: Adjustments to be made to segmented plate just going into mesh only.

6. Repeating tracking of rotor plate at 90 mc.**
7. Repeat tracking of rotor plate at 80 mc.**
8. Repeat tracking of rotor plate at 70 mc.**
9. Repeat tracking of rotor plate at 60 mc.**
10. Return dial to 100 mc. Recheck full range of 202H in 5 mc increments touching up when necessary. Upon completion of this step all dial calibration points should fall within $\pm 0.5\%$.
11. At this point the linearity measurement (See Linearity Measurement) should be made and the reactance tube (V100) Bias Adj (R107) should be set for minimum nonlinearity. The control should be locked. Recheck step 10 above after adjusting R107.
12. Coil T100 should now be coated with "Q Max" to hold wires in place to avoid changing of frequency. This preparation should be allowed to dry for 24 hours after which Step No. 10 should be repeated.**

**This adjustment would not be required in touch-up alignment and is to be used only when specific part indicated in the procedure is replaced.

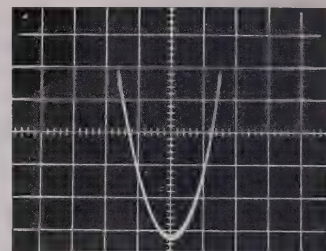


Figure 32. Doubler Tracking — Doubler Resonance Centered on Oscillator Frequency

1ST DOUBLER ALIGNMENT

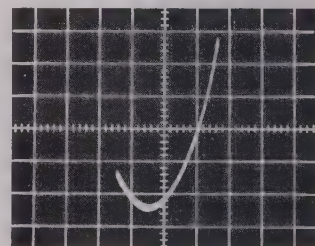
Alignment of the first doubler is done by a visual method utilizing an oscilloscope.

Preliminary Setup

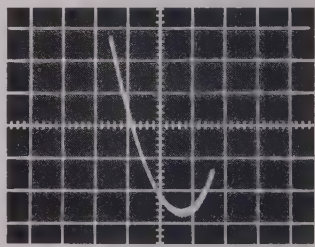
Using 250 kc deviation set on modulation meter, and 400 cps modulating frequency, the horizontal input of the oscilloscope is connected to the EXT OSC FM posts of the 202H. The vertical input is connected via the 150 k ohm scope probe to the grid of the second doubler (V103) Pin 2.

Alignment

1. With frequency dial on 108 mc, the 1st doubler trimmer is used to center the resonant frequency on 108 mc dial indication (54 mc). Fig. 32 shows proper alignment.
2. Set frequency dial on 100 mc.** By bending 1st Doubler capacitor rotor plates, in the same manner as for the oscillator, the 1st Doubler is tracked for

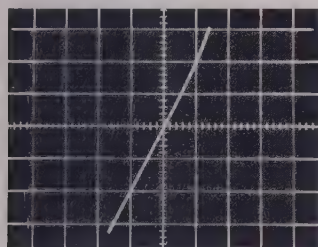


(A) Frequency of Doubler Too Low

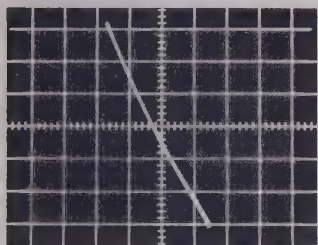


(B) Frequency of Doubler Too High

Figure 33. Doubler Tracking — Doubler Resonance within Limits of Center of Oscillator Frequency



(A) Frequency of Doubler Too Low



(B) Frequency of Doubler Too High

Figure 34. Doubler Tracking — Doubler Resonance Out of Limits of Center of Oscillator Frequency

alignment shown in Fig. 32. The following procedure should be used for bending the plates. If the scope trace is high on the right side, as shown in Fig. 33A, the capacitance is too high, and rotor plates should be bent away from stator plates. If the scope trace is low on right side, as shown in Fig. 33B, the capacitance must be increased by decreasing spacing between plates.

On initial check, the capacitance might be extremely far off. In this case, the scope trace will appear as shown in Fig. 34A and B.

Tracking of the 1st Doubler should be within 150 kc of center frequency. Fig. 33A and B shows, pictorially, the indication of the limits.

The tracking should be done at 10 mc increments to 60 mc.

Below 60 mc the doubler should be deliberately tracked about 150 kc high as shown in Fig. 33B. This is necessary to minimize FM distortion over the low frequency portion of the tuning range.

2ND DOUBLER/AMPLIFIER ALIGNMENT

The 2nd Doubler / Amplifier is aligned visually with an oscilloscope in the manner described under 1st Doubler Alignment.

Preliminary Setup

The oscilloscope vertical input is connected to Pin No. 2 of J101. Before

alignment of this stage, the output coil and attenuator must be checked for physical location with respect to each other. Fig. 35 shows the output coil (L106) and the attenuator loop (L107). The 2nd Doubler/Amplifier is aligned with 250 kc deviation modulated at 400 cps.

Alignment

1. With the range switch in the high band position, observe the oscilloscope pattern at 108 mc, setting the trimmer piston (C122) approximately one-third of the way in. Move the outside turn of the high band coil to bring the tuning into track as indicated by a symmetrical oscilloscope pattern similar to that shown in Fig. 32.

2. Set the main tuning capacitor for 216 mc and adjust the high band coil until the screen voltage of V103 for rated output from the piston attenuator is about 40 volts. The output is measured with a CW power meter such as the hp 431A, setting the attenuator for a given indicated output on the attenuator dial and adjusting the RF control until the measured output agrees. The tracking pattern should now indicate that the tank is tuned too high as in Fig. 33B.

3. Tuning progressively downward in frequency, bend the segmented rotor plates for a screen voltage of 40 to 50 volts at rated RF output. In the lower 10 mc of the band, a nearly symmetrical "in track" pattern should be obtained.**

4. Rotate the range switch to the low band position, and at 54 mc move the outside turn of the low band coil until the tuning is "in track". Tune over the entire band and verify that the tracking accuracy is within 250 kc indicated by no less than a slight hook in the oscilloscope pattern.

FM SENSITIVITY CHECK

Preliminary Setup

1. RF—54 mc.
2. INT MOD Switch—FM.
3. FREQ CPS—400.
4. DEV KC—75.
5. FM control—set for 75 kc reading on Modulation Meter.
6. Connect ac VTVM to J102.

Measurement

Reading on ac VTVM should be less than 0.35 v rms.

**This adjustment would not be required in touch-up alignment and is to be used only when specific part indicated in the procedure is replaced.

NOTE: Low FM sensitivity might require the replacement of V100. If V100 is replaced, an alignment check will be required.

The RF Unit is re-installed in the instrument as per information under Mechanical Disassembly-RF Unit. Do not assemble cover to unit.

Calibration Check

EQUIPMENT REQUIRED

hp 5243L Electronic Counter and 5253A or 5251A Frequency Converter or equivalent.*

FREQUENCY DIAL CALIBRATION CHECK

Align 202H frequency dial on shaft so calibration every 5 mc, falls within $\pm 0.5\%$ as read on frequency counter.

RF Monitor Calibration

EQUIPMENT REQUIRED

1. hp 431A Power Meter or Equivalent.*
2. hp 412A dc VTVM or Equivalent.*

PISTON ATTENUATOR CALIBRATION AND AGC ADJUSTMENT

Preliminary Setup

Position the attenuator piston so the pickup loop is approximately one-half of a wire diameter out of the attenuator tube. The pickup loop and output coil should be parallel (Fig. 35). The upper limit stop should be set with the pickup loop in this position. Connect the power meter to the 202H RF Output Jack. Set frequency to 160 mc. Attach the dc VTVM to pin No. 1 of V300 and apply power to the instrument.

Calibration and Adjustment

1. Adjust attenuator dial on shaft to indicate 0 dbm at upper limit stop.
2. Adjust attenuator to read 50K μ v on dial.
3. Adjust RF control to read 50K μ v (.05 mw) on power meter.
4. Note the dc reading on pin No. 1 of V300.
5. Reconnect the dc VTVM to pin No. 4 of J101. Adjust R308 (AGC Bias Adj.) to make reading at pin No. 4 (V300) 0.5 vdc more negative than voltage on pin No. 1 (V300).
6. Readjust RF control for .05 mw reading on power meter.
7. Recheck for 0.5 difference voltage of step 5 and repeat step 6.
8. Adjust R311 (RF Meter Adj—Hi) for "red-line" on RF Monitor Meter.

*See Recommended Equipment List under Adjustment and Calibration.

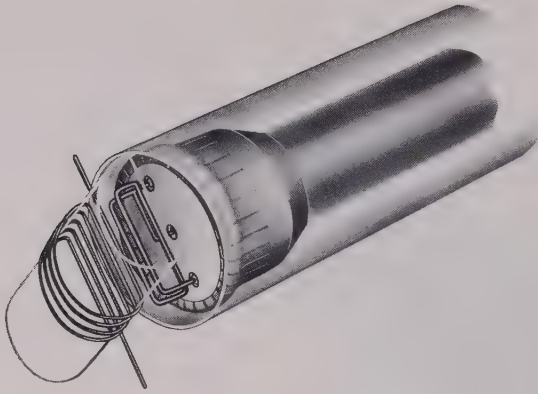


Figure 35. Output Coil-Physical Location

9. Rotate the Range Switch to the 54-108 position and adjust R313 (AGC LO-BAND ADJ) so that the 80 mc output is exactly 50 K μ v.

10. Adjust R300 (RF Meter Adj—Lo) for "red-line" on the RF Monitor Meter.

11. Connect the dc VTVM to pin No. 6 of J101. Check full frequency range of 202H while observing meter reading. The dc VTVM reading should not exceed 58 vdc.

NOTE: A higher than normal dc reading is an indication of one or more of the following defects: improper tracking, defective V103, or incorrect adjustment of steps 1 through 10.

12. Set frequency control to 54 mc. Power Meter should read 0.050 mw $\pm$.84 db.

13. Check 200K μ v attenuator setting. Power Meter should read 0.80 mw $\pm$ 1.68 db.

NOTE: If the spread between 50K μ v and 200K μ v is too great, the stop on the high limit must be reset to move the pickup loop away from the output coil at the 200K μ v setting of the attenuator dial. When stop is readjusted, repeat steps 8, 9, and 10.

14. Check the output calibration at 10 mc increments for 200K μ v and 50K μ v settings across the entire frequency range. The accuracy should be within the limits specified in Section II.

15. Rotate the Range Switch to the High Band and check output calibration at 20 mc increments across the band for 50K μ v and 200K μ v attenuator settings.

Δ F Circuitry

EQUIPMENT REQUIRED

5243L Electronic Counter and 5253A converter or equivalent.*

Preliminary Setup

1. Connect 202H directly to counter.
2. FREQUENCY MC—convenient frequency within range of 202H and electronic counter.

Adjustment

1. Set Δ F KC to -30 kc and note reading on counter.
2. Set Δ F KC to $+30$ kc. Adjust Δ F Adj (R419) for reading of 60 kc $\pm$ 7 kc as read on counter.
3. Repeat steps 1 and 2 until Δ F KC control is within 60 kc $\pm$ 7 kc for the dial calibration of -30 kc to $+30$ kc as read on frequency counter.

*See Recommended Equipment List under Adjustment and Calibration.

Generator FM Linearity or Distortion

The following is a step-by-step procedure to adjust the 202H for minimum FM distortion. Before this procedure is used, it is advisable to read the discussion on the two-signal method of linearity measurements given under Additional Information for FM Measurements—Measuring FM Linearity.

EQUIPMENT REQUIRED

1. BRC 202H or equivalent.
2. FM Receiver.
3. hp 400D or equivalent (modified—see Fig. 36).
4. hp 466A Amplifier or equivalent.
5. hp 130C Oscilloscope or equivalent.
6. Bandpass Filter. (See Fig. 36 for details).
7. Low-pass Filter (See Fig. 36 for details).
8. Miscellaneous Electrical Components (See Fig. 36 for details).
 - a. 10K Potentiometer
 - b. 20K Potentiometer
 - c. 100K Potentiometer
 - d. 250K Potentiometer
 - e. 1K Resistor
 - f. 12K Resistor
 - g. 82K Resistor
 - h. .01 μ f Capacitor
 - i. 0.1 μ f Capacitor
 - j. DPST Switch
 - k. SPST Switch

Measurement Procedure

1. Connect equipment as shown in Fig. 36.
2. Control settings on generators:

Control	Generator Under Test	Reference Generator
AM	OFF (Full CCW)	OFF (Full CW)
INT MOD Switch	OFF	AM
FREQ CPS	10 kc	50 cps
DEV KC	250	250
MOD METER Switch	FM	FM
Attenuator	0.1 v	0.2 v
RF Monitor Meter	"Red Line"	"Red Line"
FM	Full CW	Full CW
Δ F KC	O (Arrow Vertical)	O (Arrow Vertical)
FREQUENCY MC	100 mc	Difference in frequency between two generators should be IF of FM Receiver.

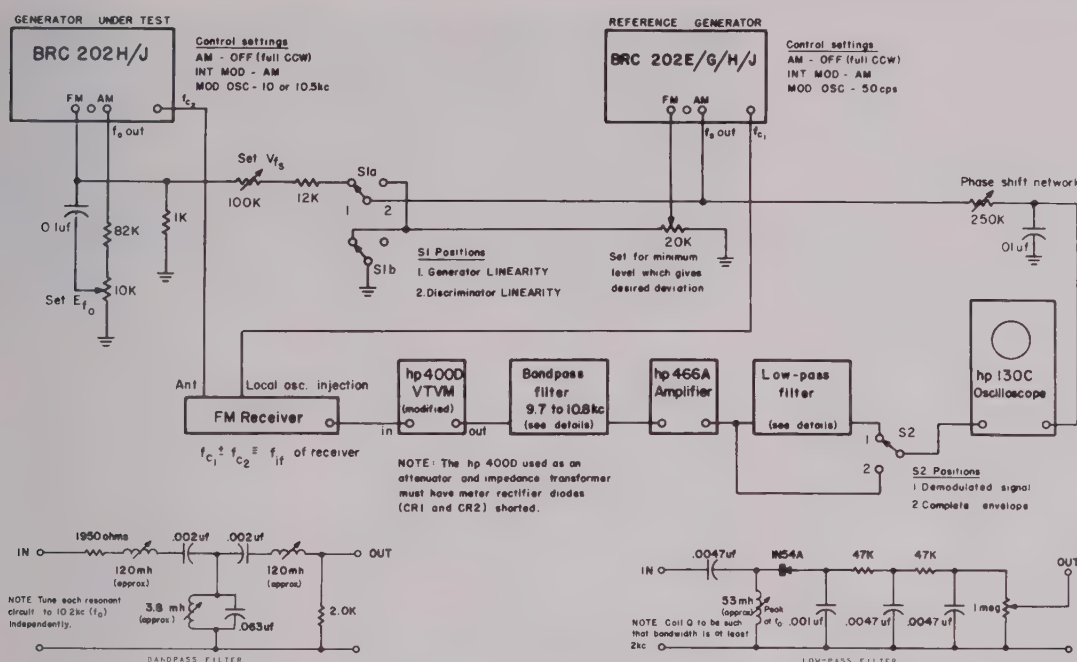


Figure 38. Setup for FM Linearity Measurement

3. Turn switch S1 to the discriminator position (Position 2).

4. Adjust 20K ohm potentiometer for approximately 80 kc deviation on the reference generator Modulation Meter. Then, using the FM control on the reference generator, set the Modulation Meter at 75 kc deviation.

5. Set the reference generator INT MOD switch to off and the test generator INT MOD switch to AM.

6. Adjust the "Set E_o" control for 15 kc deviation on the Modulation Meter (generator under test).

7. Set the test generator INT MOD switch to the off position and the reference generator INT MOD switch to the AM position. Set Switch S1 in the generator position (Position 1).

8. Adjust "Set V_r" control for 75 kc deviation on Modulation Meter (test generator). 150 kc deviation can be set precisely at this point by making a Bessel Zero calibration and observing the output of the receiver on the 400D in Fig. 36. (Diodes are not shorted.) Make sure the reference generator and test generator INT MOD Switches are OFF during a Bessel Zero calibration.

The modulation signal frequency for a first order null at 75 mc is 31,187 cps. The Bessel Zero calibration procedure is explained in detail under Additional

Information for FM Measurements—Measuring Frequency Deviation and Fidelity.

NOTE: Deviation indicated on the 400D can be used instead of the transfer oscillator method to set the deviation rotor plate (Section VI, Deviation Measurement). After making a Bessel Zero calibration, use a 400 cps modulation signal to adjust the rotor plate to give a constant meter reading on the 400D at 10 mc intervals across the frequency band.

9. Set the INT MOD switch in the generator under test to AM.

10. For FM demodulators of high output impedance, an hp 400D or equivalent should be used to provide high input and low output impedance and some attenuation (in 10 db steps). Many receivers have cathode followers or other low impedance outputs which will drive the 4K ohm bandpass filter impedance adequately. The range switch on the 400D has to be set to give an on-scale reading. However, to avoid DISTORTION, the meter diodes in the 400D have to be shorted for the measurement. Therefore, it will be necessary to set the range switch of the meter before the diodes are shorted, or use

another meter to determine the output of the receiver, and set the range switch accordingly.

11. Set switches S1 and S2 to Position 2 (Discriminator Linearity and Complete Envelope). Adjust the reference generator frequency for a symmetrical envelope. This indicates that the discriminator is operating in its most linear region. The phase shift control is now adjusted to produce an even edge on the envelope or a single line trace (Fig. 37), when S2 is the demodulated signal position.

The vertical oscilloscope gain is adjusted so that the full envelope covers 10 cm. Increase the oscilloscope gain 10 times so that 1 cm represents $\pm 1\%$ change of slope. If the oscilloscope gain can be increased 20 times without overloading, 1 cm represents $\pm .5\%$. When using the AM demodulator and low-pass filter, set S2 to position 1 (Demodulated Signal) and the oscilloscope gain can be increased 20 times (1 cm = $\pm .5\%$ change of slope).

NOTE: Should a suitable oscilloscope, such as the hp 130C, be available, the refinement of the amplitude demodulator and the nf, low-pass filter may not be needed. The nonlinearity measurements are read directly from the oscilloscope

trace (either the complete envelope or the AM demodulated trace). See Fig. 37.

12. Adjust the reference generator frequency for a symmetrical trace. At this time, check to see that the system is not being overloaded. A 2 to 1 change in RF output for either generator should not make a significant change in the scope trace. RF level adjustment may be necessary to satisfy this condition, depending on the receiver used.

13. With the reference generator frequency adjusted for a symmetrical trace the percent change of slope can be read directly from the oscilloscope. Percent change of slope is read peak to peak vertically, minus the width of the trace which may show noise.

14. Change switch S1 to the generator position. The trace on the oscilloscope now shows the combined nonlinearity of the signal generator under test and the discriminator as measured in percent change of slope. The difference in the two peak-to-peak readings is the generator percent change of slope.

With the combined nonlinearity of the generator and receiver displayed on the oscilloscope and the generator under test at 100 mc, the reactance tube bias adjustment (R107) is set to give a symmetrical trace on the oscilloscope.

15. Repeat steps 13 and 14 until the trace on the oscilloscope is symmetrical in both positions of S1.

16. Adjusting the 202H for minimum distortion using an entertainment FM receiver and a distortion analyzer is not suggested because the resulting distortion reading is a composite of the generator plus the receiver, and it is possible to adjust the 202H so that distortion complements that of the receiver. Adjusting a 202H in this manner does not assure adjusting the generator for minimum distortion.

NOTE: Due to the variation in quality of commercial FM receivers, three situations can arise at this point.

1. No visible change in the oscilloscope pattern when Switch S1 is changed and the reactance tube bias is adjusted. This will occur with a receiver that has appreciable greater distortion than the 202H and the added distortion or nonlinearity of the 202H is not noticeable compared to that of the receiver. This receiver cannot be used.

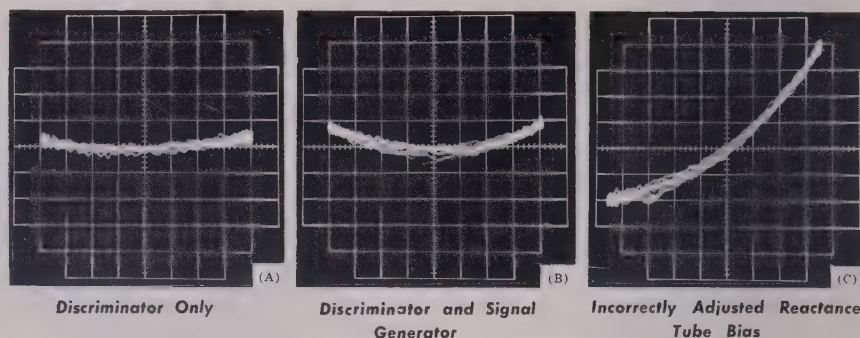


Figure 37. Typical Change of Slope During Linearity Measurement

2. The difference in the peak-to-peak percent change of slope readings of discriminator alone and the discriminator plus generator is approximately equal to the reading for the discriminator alone. This will occur if a receiver is used with distortion comparable to the 202H (less than 0.5%).

3. The oscilloscope trace in the discriminator position of S1 is an approximately flat line with the oscilloscope gain set to $\pm 0.5\%$ change of slope per division. This will occur with a receiver of telemetry quality that exhibits approximately 0.1% change of slope at 75 kc deviation. If a receiver of this quality is available the percent change of slope observed in the generator position of S1 will be mainly due to the 202H and the reactance tube bias adjustment can be easily set to minimize the 202H distortion. A receiver of this quality and linearity may be used to check relative distortion across the frequency bands of the 202H after the reactance tube bias adjust has been set at 100 mc for minimum change of slope (step 14). It should be noted that the distortion indicated is the combined distortion of the 202H plus the receiver.

Deviation Measurement

The following procedure is for adjusting the deviation rotor plate and the FM Mod Meter.

EQUIPMENT REQUIRED

1. hp 540B Transfer Oscillator or equivalent.*
2. hp 5243L Electronic Counter or equivalent.*
3. hp 5253A Frequency Converter for Electronic Counter.*
4. hp 5251A Frequency Converter for the electronic counter.
5. hp 130C Oscilloscope or equivalent.*
6. hp 650A Test Oscillator or equivalent.*

Preliminary Setup

1. Connect equipment as shown in Fig. 38.
2. Set the 202H Generator controls as follows:

Control	Setting
Frequency Megacycles	54 mc
Mod Meter Switch	FM
INT MOD Switch	OFF
AM Control	Full CCW
Dev KC Switch	250 kc

3. Set the Test Oscillator to 400 cps with approximately 2 volts output.

*See Recommended Equipment List under Adjustment and Calibration.

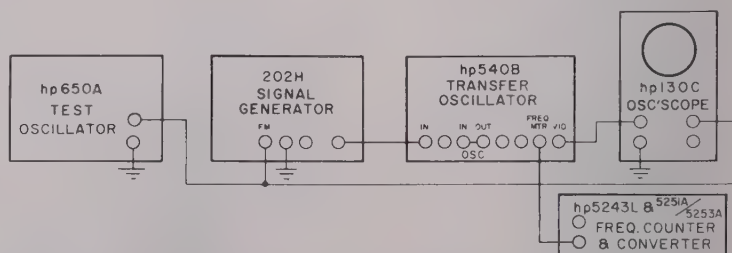


Figure 38. Setup for Deviation Measurement

DISTORTION MEASUREMENT—AM

NOTE: The following procedure can only be performed after the FM Modulation Meter Adjustment, as described under Deviation Measurement.

Preliminary Setup

1. Add distortion analyzer to set-up in Fig. 39. The distortion analyzer is connected to the 202H as shown in Fig. 42.
2. INT MOD Switch — OFF.
3. Generators adjusted for zero beat at 54 mc.
4. Audio oscillator input to read 30% modulation (as shown in trapezoidal presentation on oscilloscope).

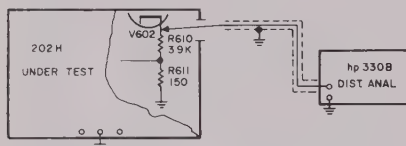


Figure 42. Setup for AM Distortion Check

Measurement

1. Check distortion. Distortion should be less than 5%.
2. Repeat distortion measurement at 108 mc. Distortion should be less than 5%.
3. Repeat distortion measurement at 108 mc (High Band), 160 mc and 216 mc. Distortion should be less than 5%.
4. Increase AM input for 50% AM on meter.
5. Check distortion at 54 mc, 108 mc (Low Band), 108 mc (High Band), 160 mc and 216 mc. Distortion should be less than 8%.
6. Increase AM input for 50% AM on meter.
7. Check distortion at 54 mc, 108 mc (Low Band), 108 mc (High Band), 160 mc and 216 mc. Distortion should be less than 20%. The diode detector in the RF Unit will cause distortion at high modulation levels.

ADDITIONAL INFORMATION FOR FM MEASUREMENTS

Measuring FM Linearity

What do we really mean by "non-linearity", and the distortion which results therefrom? Nonlinearity refers to that characteristic of a circuit which causes the output to be related to the input by other than a straight line function. As a result, the circuit may not be specified by linear differential equations with time as the independent variable. Many terms are used to describe distortion due to this concept of nonlinearity.

Nonlinear Distortion has been defined by the IRE Standards on Circuits as "Distortion caused by a deviation from a desired linear relationship between specified measures of the output and input of a system". The related measures need not be output and input values of the same quantity; e.g., in a linear detector, the desired relation is between the output signal voltage and the input modulation envelope. There are specific means of measuring non-linearity among which are *Total Percent Harmonic Distortion* and *Intermodulation Distortion*. It may be felt that, somehow, there is a large difference between intermodulation distortion (IM) and total percent harmonic distortion (HD). While there may be advantages in one system of measurement or the other, it should be remembered that finite results in either an IM or HD measurement occur due to nonlinearity of the transfer characteristic, and measurement by either method may be analytically related for any specific shape of curve.

NONLINEARITY MEASUREMENT TECHNIQUES

In the simple case of amplitude modulation, it is possible, by means of a suitable wave analyzer, to measure the frequency spectrum resulting from the modulation process. If the modulation signal is free of distortion and the modulation process is perfectly linear, the resulting spectrum in the vicinity of the carrier will contain only the carrier and the two sidebands, separated from the carrier by the modulation frequency as seen in Fig. 43A. If nonlinearity of the transfer characteristic exists, the results may be as shown in Fig. 43B. Here, the appearance of sidebands, separated from

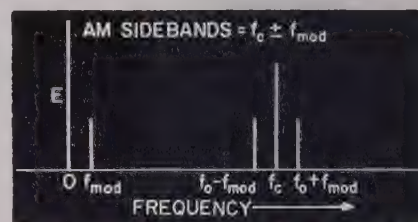


Figure 43A. Undistorted AM Spectrum

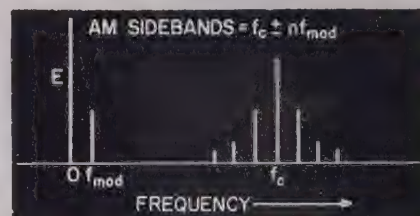


Figure 43B. Distorted AM Spectrum

the carrier by integral multiples of the modulating frequency, is not only qualitative evidence of nonlinear distortion, but affords a measure of this distortion if the amplitudes of all the sidebands relative to the carrier are determined.

In the FM case, for deviations and modulation frequencies for which the modulation indices, defined as

$$m = \frac{\text{peak deviation}}{\text{modulating frequency}}, \text{ are appreciably greater than unity (the usual case), the resulting frequency spectrum becomes exceedingly complex, even for an undistorted modulation process. In the presence of nonlinearity of the frequency modulator, the spectrum becomes even more complex; thus ruling out spectrum analysis as a simple means of measuring nonlinearity.}$$

A second method for measuring a frequency modulator transfer characteristic is possible, if the modulator is capable of operation at dc. This method consists of introducing a known increment of modulating voltage and measuring the resulting frequency increment. Its precision is limited by the stability of the carrier frequency in the absence of modulation and the ability to read small increments in voltage and frequency precisely. Modern measuring equipment has solved the latter two problems, but not the former.

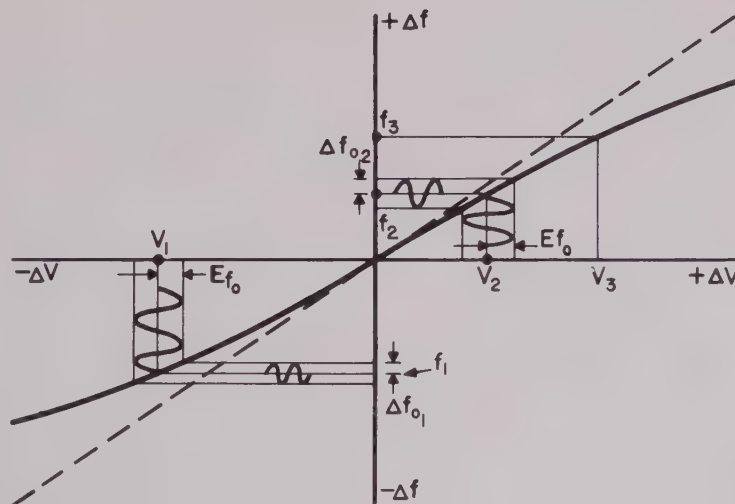
In addition to the matter of precision, it is desired to be able to make adjustments on the frequency modulator for minimum nonlinearity as a result of an instantaneous display of nonlinearity of the frequency modulator.

New FM Linearity Measurement Method

In order to best understand the method to be described, let us resort to a general discussion of a circuit which relates a change in voltage to a change in frequency or vice versa. This covers the general case of frequency modulators and demodulators. Reference to Fig. 44 will show the transfer characteristic of such a circuit. The horizontal axis represents changes in voltage and the vertical axis changes in frequency. Shown dotted is a reference straight line which passes through the origin, as does the arbitrary nonlinear curve. The problem is to measure the departure of the actual curve from the ideal straight line. Here, the reference straight line chosen is that line for which the rms sum of the differences between the actual curve ordinates and the straight line ordinates is a minimum.

Fig. 44 shows that one way to describe the departure of the curve from the straight line is to measure a large number of individual ordinates of the actual curve, subtract them from the ordinates of the straight line, and report the differences in tabular or curve form. This technique is not instantaneous, even when automated.

It is also evident in Fig. 44 that if the slope of the actual curve could be compared, at any point, with that of the straight line, a relationship covering the nonlinearity could be readily developed. Thus, it should be possible to make an incremental measure of the slope of the curve by introducing a small amplitude sine wave of voltage, E_{f_0} , superimposed on a direct voltage. The direct voltage may then be varied. If the resulting frequency variation, due to the small constant amplitude search voltage, E_{f_0} , were measured at each value of V , and plotted as a function of V over the entire range of interest of the voltage axis, a plot of the varying slope of the actual transfer characteristic would result. The extent to which this departs from the slope of the straight line, is a measure of the nonlinearity of the transfer characteristic. This can be done dynamically by allowing V to vary over the desired dynamic range at a sinus-



Definition of Terms

- E_{f_0} = Constant Amplitude "Search" Voltage
- $V_1; V_2; \dots; V_k$ = Arbitrarily Chosen Operating Points
- Δf_{0k} = Frequency Deviation at Rate f_0 and at Operating Point V_k
- K_k = Slope of Solid Curve at any Point k
- $\Delta f_{0k} = K_k \cdot E_{f_0}$
- As $E_{f_0} \rightarrow 0$; $\frac{\Delta f_{0k}}{E_{f_0k}} \rightarrow \frac{df}{dE}$

Figure 44. Transfer Characteristic with Typical Nonlinearity

oidal rate, f_s . The slope of the transfer characteristic can be plotted on an oscilloscope by driving the vertical axis with an amplitude proportional to Δf_0 and the horizontal axis with a voltage proportional to V , and varying at rate f_s .

Consider the case of a linear frequency modulator and frequency demodulator, to which the two test voltages, E_{f_0} and V_{f_s} , are applied with the understanding that V_{f_s} is of such magnitude as to sweep through the entire dynamic range of interest, and that E_{f_0} is very much smaller than V_{f_s} , typically one-tenth as great. This situation is shown in Fig. 45.

As might be expected, the output spectrum of the linear demodulator driven by the linear modulator is simply E_{f_0} and V_{f_s} , with the amplitude relationship established by the input. Now, assume that the frequency modulator is linear, but that the frequency demodulator is nonlinear (curve of the nature shown in Fig. 44). If E_{f_0} were to be plotted as a function of V_{f_s} , it would approximately plot the slope of the transfer characteristic being studied, namely, that of the assumed nonlinear

demodulator. Therefore,

$$\Delta f_0 = \frac{df}{dV} (E_{f_0}),$$

where df/dV is recognized as the slope of the transfer characteristic in Fig. 44.

Another view of the same phenomena is shown in Fig. 45B. This shows the output spectrum of the nonlinear demodulator driven by the linear modulator, and with the input as assumed previously. The output spectrum is now far more complicated than in the linear case (Fig. 45A), consisting not only of V_{f_s} and E_{f_0} , but also of integral multiples with decreasing amplitude of both f_s and f_0 , and sum and difference frequency terms resulting from the nonlinearity of the transfer characteristic.

Fig. 45C shows the df/dV curve as determined by plotting the amplitude of Δf from the demodulated output as a function of V_{f_s} . This would be an accurate plot of the transfer characteristic slope if the magnitude of E_{f_0} in the input were made vanishingly small compared to V_{f_s} . This approximation is entirely satisfactory if $V_{f_s}/E_{f_0} \approx 10$. It should be emphasized that Fig. 45C and

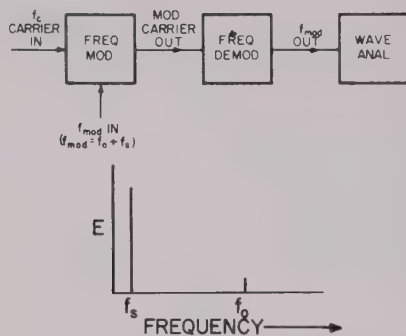


Figure 45A. Linear AM and FM Demodulator with Output Spectrum

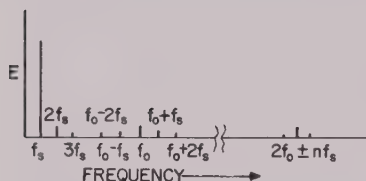


Figure 45B. Nonlinear FM Demodulator — Linear FM Modulator Spectrum

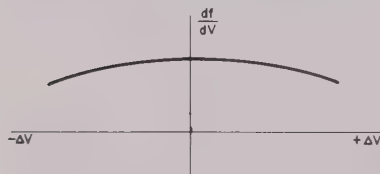


Figure 45C. Plot of df/dV of Figure 42

the spectrum plot of Fig. 45B contain the same information concerning the transfer characteristic nonlinearity, but displayed in a different manner. The question now is, how may a simple display be achieved?

The block diagram of Fig. 46 shows the introduction of a bandpass filter which accepts f_0 and the significant sidebands about it due to f_s , and the display of the resulting carrier envelope on the vertical axis of an oscilloscope. The horizontal axis is driven by the initiating V_r from the input of the frequency modulator. Fig. 47 shows a typical result. Since the demodulated signal is passed through a bandpass filter, the upper and lower section of the envelope presented to the oscilloscope must be symmetrical; therefore, either may be selected for consideration. Where the amplitude of the f_s sidebands about f_0 is very low, as would be true of a highly linear circuit, the resulting departure of the oscilloscope trace from a rectangle is small. Ignoring half the envelope, it is possible to offset the centering of the oscilloscope

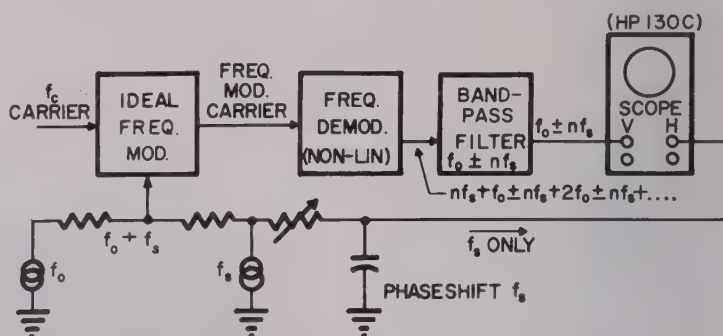


Figure 46. Block diagram of Circuit Used to Provide Instantaneous Display of Transfer Characteristic Change of Slope

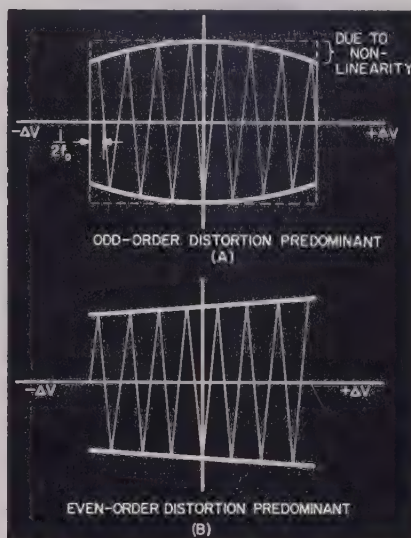


Figure 47. Typical Display from Circuit in Figure 46

and greatly expand either half of the display. This permits measuring changes in slope down to about 0.1% of one-half the envelope.

The departure of the envelope in this display from a reference value (chosen as the slope at the origin of Fig. 44, and appearing on the vertical center line of the oscilloscope displays in Fig. 47), is a direct measure of the change in slope of the transfer characteristic. Therefore, the slope of this curve is approximately the second derivative of the transfer characteristic. If the envelope shows symmetry about the vertical center line of the trace (Fig. 47A), it can be shown that this is a result of odd-order harmonic distortion. If the envelope is asymmetrical about the vertical center line, and has mirror image symmetry about the horizontal center line (Fig. 47B), the distort-

tion is largely even-order. Thus, it can be seen, that much information is contained in the displays of Fig. 47, produced by the circuit of Fig. 46.

Up to this point a linear modulator has been assumed. Where is the perfectly linear modulator available? The technique illustrated in the block diagram of Fig. 48 shows a method of "synthesizing" an FM signal, modulated simultaneously by two frequencies (f_0 and f_s), in which sidebands of f_s around f_0 are not produced, even though the individual signal generators have some nonlinear distortion. The technique used is the receiver practice of mixing an incoming signal with a local oscillator and amplifying at a fixed intermediate frequency before frequency demodulation is performed. Then, consider the linearly demodulated spectrum produced by modulating either signal generator by a single frequency, remembering that one generator is modulated by f_s and the other by f_0 . The output spectrum from a perfect demodulator, driven by a nonlinear modulator with single frequency input, would consist of the original modulating frequency and integral multiples of this frequency, generally in decreasing magnitude. Since the two frequencies f_s and f_0 do not

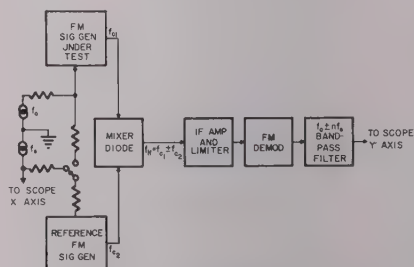


Figure 48. Block Diagram of Circuit for Synthesizing Perfectly Linear Modulation

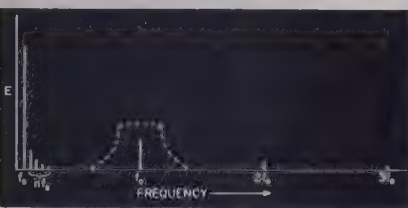


Figure 49. Demodulator Output Spectrum of nf_s and nf_o with Superimposed Bandpass Filter — Linear Case

simultaneously exist in either frequency modulator, it is not possible to produce sum and difference frequencies in the linearly demodulated output. (See Fig. 49). When the carrier frequencies (f_{c1} and f_{c2}) generated by the two FM sources (one modulated by f_s and the other by f_o) are mixed at RF (Fig. 48), and the difference carrier frequency is amplified by a suitable selective amplifier, the instantaneous frequency in the selective amplifier is the simple arithmetic difference of the instantaneous frequency modulated sources. Thus, no sum and difference frequencies of the modulating signals f_s and f_o appear in the FM signal at average frequency, f_{c1} .

Now, introduce a bandpass filter centered on f_o in the output of the demodulator. The bandwidth of this filter must be wide enough to accept the significant sidebands of f_s about f_o . It has been found that acceptance of sidebands up to the 3rd is sufficient. This bandpass is shown by dotted lines in Fig. 49. It will be seen that this filter eliminates f_s and all of the distortion products due to the nonlinearity of the frequency modulators in the individual signal generators which produce the difference frequency, f_{c1} .

Now, consider the effect of nonlinearity in the frequency demodulator when driven by a signal generated by the circuit of Fig. 48. It is evident that the spectrum will consist not only of the components shown in Fig. 49, but of sidebands about f_o and its harmonics spaced by nf_s . (See Fig. 50.) If the output of the bandpass filter is connected to an oscilloscope, an envelope, similar to that of Fig. 47, will be seen. Thus, a technique is available for using two signal generators of finite modulator nonlinearity to synthesize an apparently distortionless signal which may then be used to measure the nonlinearity in a frequency demodulator.

To avoid the necessity of offsetting the axis of the oscilloscope display and

expanding the scale to look at small deviations of the envelope from rectilinearity, it is possible to eliminate the carrier with a linear amplitude demodulator. The composite block diagram of Fig. 51 shows the application of a simple linear AM detector followed by a low-pass filter to eliminate the carrier, f_o , from the display. The output from the linear detector will be a direct current component proportional to the peak amplitude of f_o , together with the envelope produced by the nf_s sidebands beating with the carrier. The percentage change in slope, compared to a straight line, may be read by expressing the peak value of the demodulated envelope as a percentage of the dc component (which is proportional to the peak value of f_o).

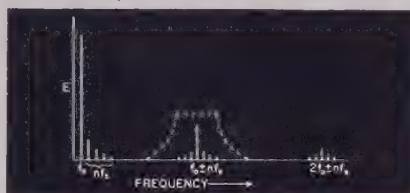


Figure 50. Demodulator Output Spectrum of nf_s and nf_o Including nf_s Sidebands About f_o — Nonlinear Case

If the output of the AM detector and nf_s low-pass filter is read on an averaging meter, an average value of the percent change in slope will be read. The amplitude of the significant harmonics (2nd and 3rd) of f_s usually has been relatively low, so the value read by an rms calibrated, average reading meter closely approximates the rms value of the departure of the slope of the transfer characteristic from the constant slope of the ideal straight line. Since the departure of the transfer charac-

teristic of Fig. 44 from a straight line necessitates a change in the slope of the transfer characteristic, it is seen that these are related effects. Calculations have shown that the numerical values for percent change in slope are always less than the values for percent departure of the transfer characteristic from a straight line. The specific relationship depends on the actual shape of the curve, however, for transfer characteristics experienced in FM modulators and demodulators. The ratio of percent departure from a straight line to percent change in slope from that of a straight line varies from 1/2 to 1/3. Thus, a measurement of 1% change in slope insures a departure of the transfer characteristic from a straight line of less than 1%.

Fig. 51 shows a composite block diagram of the entire setup with a few additional features. Instead of separately modulating the signal generator under test and the reference signal generator with f_s and f_o respectively, if the signal generator under test is simultaneously modulated by f_s and f_o (by switching S_1) the change in slope of the frequency modulator of the signal generator under test will be superimposed upon that of the FM demodulator. Thus, if the individual ordinates of the display produced by the block diagram in Fig. 51 are noted for the case of separate modulation, and then determined for the case of simultaneous modulation of the signal generator under test, the algebraic difference of these ordinates will produce a curve which is due to the nonlinearity of the FM signal generator under test only, and does not depend upon that of the frequency demodulator. Note that when

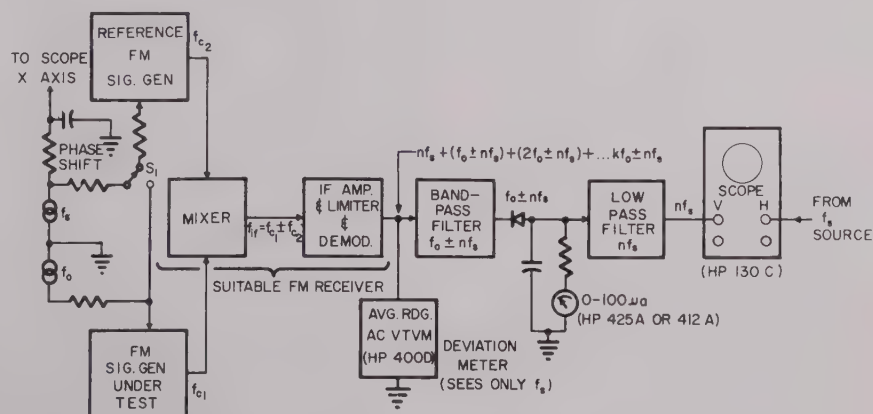


Figure 51. Block Diagram of Circuit Used to Obtain Change of Slope Display

switching f_c from one generator to the other, the horizontal polarity of the display is reversed.

Thus, a circuit and measuring technique have been developed which will measure the change in slope of a frequency modulator largely independently of the demodulator, as well as the change in slope of the demodulator independently of the frequency modulator.

Measuring Frequency Deviation and Fidelity

There are in use today several methods of measuring the frequency deviation of a frequency modulated signal. However, there is one method which is both straight forward and accurate, requiring the use of commonly available laboratory equipment. This method is known by various names, probably the most used of which is "The Bessel Zero Method". As this name implies, it is related to the Bessel functions, the zero-order Bessel function J_0 in particular. The fact that the zero-order function passes through zero amplitude at certain points, which correspond to discrete modulation indices, forms the useful basis for the method, a heterodyne type receiver is tuned to the unmodulated carrier frequency of the source to be tested so that a beat frequency of some several hundred cycles is obtained, which can be monitored with earphones or a voltmeter. As a carrier is frequency modulated by a single frequency, the beat frequency will be observed to disappear at several points as the amplitude of the modulating signal is increased. As previously stated, these null points correspond to specific modulation indices, the first five of which are:

2.4048
5.5201
8.6537
11.7915
14.9309

These five points are graphically illustrated by the curve of the zero-order Bessel function in Fig. 52. The modulation index being the ratio of frequency deviation to modulating frequency, it becomes apparent that knowing the indices at which the carrier is zero and knowing the modulating frequency, the frequency deviation at each carrier zero is readily determined.

As an illustration, let us take a value of 10,000 cps for the modulating frequency. As the amplitude of the modu-

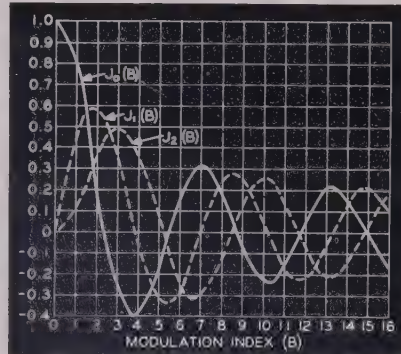


Figure 52. Bessel Functions of the First Kind
If the modulating signal is increased, nulls will be obtained at the deviations of 24.1, 55.2, 86.5, 117.9 and 149.3 kc.

It is well to bear in mind that in order to perform this test with any degree of success, it is necessary that the modulating frequency be considerably greater than the beat frequency being monitored. This is so because the sidebands of a frequency modulated signal are spaced at intervals equal to the modulating frequency (see Fig. 53). If such is not the case and the ratio of modulating frequency to beat frequency is, for an extreme case, only of the order of 2 to 1, the possibility exists of beating with the first side-band frequency rather than the carrier. If unknown to the operator this will produce erroneous results, since the sidebands, like the carrier, pass through points of zero amplitude at particular modulation indices (see Fig. 52).

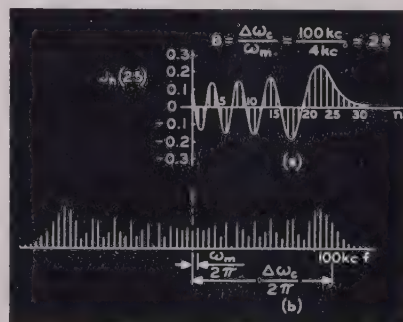


Figure 53. Bessel Functions and Frequency Spectrum for $f_m=4kc$ and $\Delta f_c=100kc$

The accuracy to be expected from this method is dependent upon the accuracy of the modulating frequency and how well the nulls can be defined. For example, let us assign a value of $\pm 0.5\%$ as the accuracy of the modulating frequency. Holding the modulation index

constant, this $\pm 0.5\%$ is applied directly to the frequency deviation. Further, let us assume that the sensitivity of our system is such that the smallest amplitude beat-frequency we can detect is 40 db below the beat-frequency signal due to the unmodulated carrier. Because the receiver signal amplitude remains constant, the amplitude of the beat frequency varies directly as the amplitude of the carrier frequency of the source under test. If we arbitrarily assign a value of 1 to the amplitude of the beat-frequency due to the unmodulated carrier, we may interpolate directly from a table of zero-order Bessel functions to determine the definition of the nulls. Now, 40 db below 1 is 0.01, which we can locate in the table in the vicinity of the first zero point. If what we believe to be 0 is actually 0.01, then the modulation index we obtain is approximately 2.38 instead of 2.4048, or an error of about 1.0%, which if the Bessel curve is assumed linear in the vicinity of zero, it is possible on either side of zero, or $\pm 1.0\%$. For this case, if we hold the modulating frequency constant, this error too is applied directly to the deviation frequency. Taking both errors into account, for this example the maximum possible error in determining the deviation frequency at a modulation index of 2.4048 is $\pm 1.5\%$. Because the slope of the zero-order Bessel curve decreases as it passes through zero at higher modulation indices, the maximum possible error in determining frequency deviation will increase slightly with higher modulation indices.

The minimum receiver bandwidth that can be used with VHF FM generator of good stability limits the modulation frequency to a minimum of about 5 cps. This puts a limit of approximately 12 kc on the minimum deviation that can be measured by Bessel nulls. On the other hand, nulls above the 4th order become difficult to identify and precisely locate. This limitation is not serious because most Signal Generators and FM telemetry receivers are quite flat from 50 cps to 15 kc. The Bessel Null method fails, and hence a problem arises in measuring FM fidelity at small modulation indices when modulation frequencies of 10 kc to several megacycles are used at relatively small deviations. For instance, a deviation of 50 kc at a modulating frequency of 500 kc gives a modulation index of 0.1.

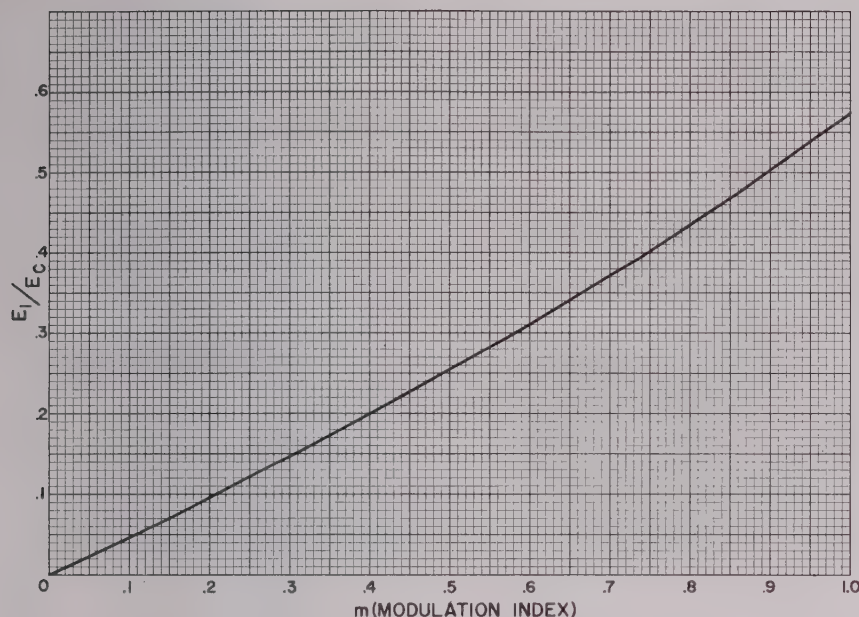


Figure 54. Amplitude Ratio — m vs. E_1/E_c .

Since the first order Bessel null appears at $m = 2.4048$, that is the minimum value of "m" useable with the Bessel null method. A ratio measurement of sideband to carrier amplitudes fills this gap. This ratio E_1/E_c equals $J_1(m)/J_0(m)$ because $E_1 = E_c J_1(m)$ and $E_c = E_c J_0(m)$.

The carrier amplitude $E_c = E_c J_0(m)$, the first order side-band amplitude $E_1 = E_c J_1(m)$, and the nth order sideband amplitude $E_n = E_c J_n(m)$ where E_c is the amplitude of the unmodulated carrier. The ratio under consideration is E_1/E_c . This equals the Bessel Function ratio $J_1(m)/J_0(m)$, which in turn is a function of the modulation index (m). Therefore since f_{mod} is known and "m" can be determined from E_1/E_c , the actual deviation can be calculated. E_1/E_c equals $J_1(m)/J_0(m)$. If $J_1(m)/J_0(m)$ is known "m" can be found in any table of Bessel functions of the first kind (See Fig. 52). For convenience m vs. $J_1(m)/J_0(m)$ is plotted in Fig. 54. The values of $J_1(m)/J_0(m)$ or E_1/E_c for some of the more common modulation indices are listed in Table I.

For the sideband method to give accurate results, the FM spectrum cannot be distorted by AM. Residual AM on an FM spectrum increases the amplitude of one sideband and decreases the amplitude of the other as shown in Fig. 55.

An amplitude sideband measurement set up which eliminates the need for a

receiver of known fidelity is shown in Fig. 56 and Fig. 57. By operating the Signal Generator under test at 0.2v output and the beating generator at 0.1v (through the series R in the mixer), the amplitude of the intermediate frequency, f_{if} , going into the receiver is limited, removing any AM. This presents a nearly pure FM spectrum for measurement.

An intermediate carrier frequency of approximately 20 mc is used so the separation between the carrier and sidebands is a larger percentage of the carrier frequency than it would be using the signal generator carrier frequency. It is necessary to use an intermediate frequency due to the selectivity limitations of receivers.

The signal strength is indicated on a VTVM connected to the receiver's second detector output which varies linearly with the signal. The meter does

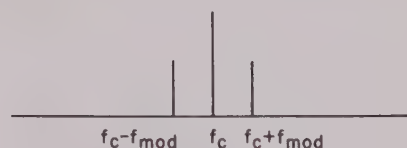


Figure 55A. Undistorted FM Spectrum



Figure 55B. AM Distorting Spectrum

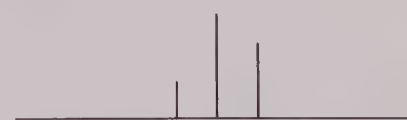


Figure 55C. FM Spectrum with Effect of AM

not measure the absolute amplitudes of the carrier and sidebands but is used to measure the relative amplitudes by setting a constant RF level at the receiver input.

There are two ways to measure the sideband to carrier ratio. The first, and probably the faster, shown in Fig. 56, uses step attenuators to determine the amount of attenuation needed to reduce the carrier amplitude down to the sideband amplitude. This gives the ratio E_1/E_c directly in decibels.

The second method uses a reference generator operating at the intermediate frequency, matching its output level, as indicated on the VTVM, to the levels of the carrier and sideband (Fig. 57).

Regardless of which method is used the modulation signal must be held at a constant amplitude over the range of modulation frequencies used.

m	Δf (kc)	f_{mod} (kc)	E_1/E_c	
			RATIO	db
1.0	50	50	.575	—4.8
.5	50	100	.258	—11.7
.25	50	200	.125	—18

TABLE I. Modulation Indices ($m = \frac{\Delta f}{f_{mod}}$)

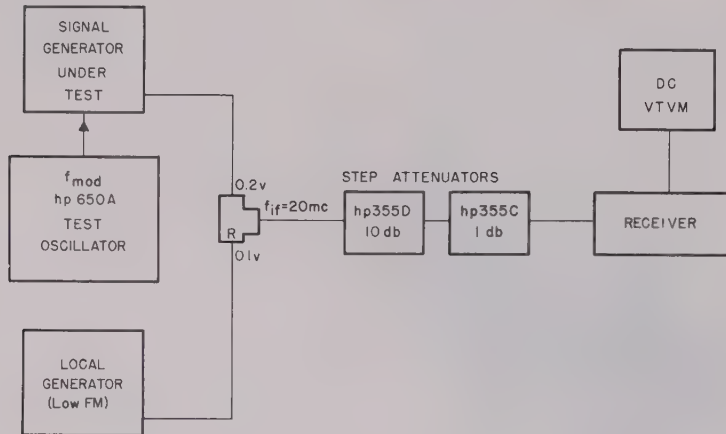


Figure 56. Fidelity Measurement — Step Attenuator Method

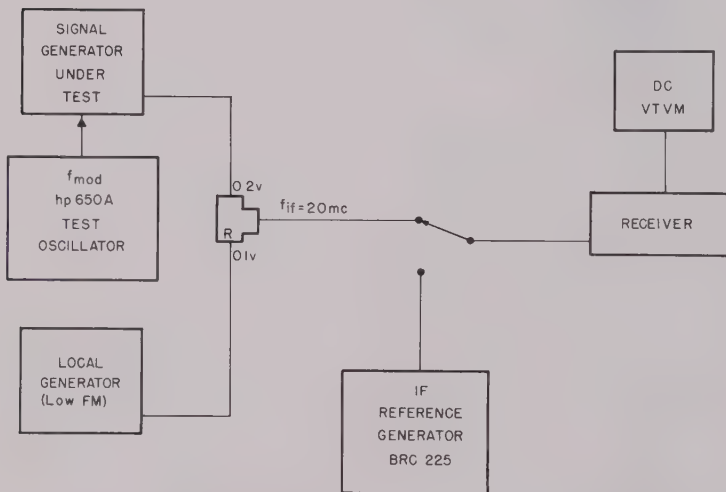


Figure 57. Fidelity Measurement — Reference Generator Method

The amplitude is set for the run by making a Bessel null calibration for 50 kc deviation or whatever deviation is being measured. The second order null for 50 kc deviation occurs at $f_{mod} = 9.058$ kc. Using a frequency counter set the frequency of the modulation source. Tune to the carrier with no modulation and then increase the amplitude of the modulation signal until the second order null occurs. The null can be detected on the meter or ear-phones. The amplitude of modulation frequency which produces the second order null will be used for the rest of the measurements and the results will be based on a known 50 kc deviation reference. It is now known that at f_{mod} of approximately 10 kc "X" volts of modulation signal gives 50 kc deviation. We want to know how close the

deviation will be to 50 kc for "X" volts at other modulation frequencies. Now that the amplitude of the modulation signal has been set, the fidelity measurement can be made.

In the set-up (Fig. 56), with the step attenuators set to at least 40 db, the receiver is tuned to the unmodulated IF carrier. Apply the modulation signal, being careful to set its amplitude to the same values obtained for the 50 kc deviation Bessel Null. Adjust the receiver RF gain to give a convenient upscale reading on the VTVM. Tune to the sideband frequency $f_{if} \pm f_{mod}$ and reduce the step attenuation until the VTVM indicates the same receiver RF level as that set for the modulated carrier. The hp 355C step attenuator has 1 db steps, however,

the VTVM can be interpolated to at least .25 db.

For a modulation frequency (f_{mod}) of 100 kc and a deviation (Δf) of 50 kc the modulation index:

$$m = \frac{\Delta f}{f_{mod}} = 0.50.$$

From the graph in Figure 54 or Table I, the ratio of E_1/E_c for $m = 0.5$ theoretically equals 0.258 or —11.7 db. The 202H FM fidelity specification is ± 1 db from 5 cps to 200 kc. Therefore, a —10.7 to —12.7 db ratio for E_c/E_1 at $f_{mod} = 100$ kc and $\Delta f = 50$ kc would be within specification.

If, for example, the ratio E_1/E_c measured —12.2 db at this modulation index, the generator or transmitter FM fidelity would be 0.5 db below the theoretically ideal unit. Figure 54 is nearly linear at the low values of "m" and E_1/E_c . Therefore, if E_1/E_c is 0.5 db (6%) low, "m" will also be 6% low. The actual modulation index is 0.47 compared to the theoretical value of 0.50. This means that "X" volts of modulation which gave 50 kc deviation at 10 kc does not give 50 kc deviation at $f_{mod} = 100$ kc, but actually gives a deviation of:

$$\Delta f = mf_{mod} = 0.47 \times 100 \text{ kc} = 47 \text{ kc}.$$

The second method (Fig. 57), using the reference generator, uses the same intermediate frequency and the modulation signal amplitude as before, as determined by a 50 kc deviation Bessel Null. The receiver is tuned to the unmodulated IF carrier from the mixer and is then switched to the reference generator tuned to the same IF. The reference generator attenuation output is set to 2 K μ v, the modulated carrier (E_c) reference level. Adjust the receiver gain for a convenient upscale reading. Switch the receiver back to the beating generators, apply the modulation signal to the test generator and adjust the local generator output so the VTVM indicates the same level as it did for the 2 K μ v from the reference generator. The carrier amplitude of the modulated IF is now 2 K μ v. Make sure it is the carrier by momentarily removing the modulation signal. The carrier will not disappear when the modulation signal is removed. With the modulation signal back on, tune the receiver to the upper or lower sideband. Change the VTVM range and/or adjust the receiver gain to get an upscale reading for the sideband. Switch to the

reference generator; adjust the frequency to the sideband frequency of $f_{if} \pm f_{mod}$, and adjust its attenuator to give the same reading as the sideband on the VTVM.

The reference generator attenuator reading over the 2 K μ v carrier reference equals E_1/E_c .

As an example, for $f_{mod} = 200$ kc and $\Delta f = 50$ kc, $m = 0.25$. Referring to the graph in Fig. 54 or Table I, we

see that $m = 0.25$ results in a sideband ratio, E_1/E_c , of 0.125 or -18 db. Therefore, with a carrier level of 2 K μ v, the first-order sideband amplitude should be 2 K μ v $\times$.125 $\pm$ 250 μ v. A specification of ± 1 db at $f_{mod} = 200$ kc means the sideband will be within $\pm 12\%$ of its ideal values or 220 to 280 μ v with $m = .25$ and 2 K μ v carrier. Again, using the linearity of Fig. 54, suppose the ratio of E_1/E_c measured 0.120 (4% low) instead of 0.125

at $f_{mod} = 200$ kc. In this case "m" would also be 4% low. Therefore, instead of 50 kc deviation at $f_{mod} = 200$ kc for "X" volts modulation, as was the case at $f_{mod} = 10$ kc, there will be 4% less deviation or 48 kc.

To make sure that the IF signal is properly limited, check both the upper and lower sidebands to see if AM is distorting the spectrum. If AM is present, it can be minimized by adjusting the levels of the two signals.

SECTION VII

REPLACEMENT PARTS

Tables of replaceable electrical and mechanical parts for the 202H are included in this section. Locations of these parts are given in Fig. 58 through 67 inclusive. When ordering replacement parts, specify the BRC part number and the description given in the replacement parts tables. See Section VI — Maintenance, for detailed disassembly and assembly procedures and for adjustment and/or calibration procedures required after component replacement.

LIST OF MANUFACTURERS

Abbrev.	Manufacturer's Name
AB	Allen-Bradley Company
AEI	Arco Electronics, Inc.
AER	Aerovox Corporation
AH	Arrow-Hart & Hegeman Electric Company
BC	Bendix Corporation
BI	Beckman Instrument, Inc., Helipot Division
C-D	Cornell-Dublier Electric Corporation
CEC	Corning Electronic Components, Corning Glass Works
CMC	Clorostat Mfg Co., Inc.
CRL	Centralab, Div. of Globe-Union, Inc.
CTS	CTS Corporation

Abbrev.	Manufacturer's Name
CWE	Continental - Wirt Electronics Corp.
DE	Dale Electronics, Sub. Hathaway Instruments
DEC	Dage Electric Co., Inc.
EMC	Electro Motive Mfg. Company
ERC	Erie Resistor Corporation
FTC	Freed Transformer Company
GA	Good-All Electric Mfg. Company
GE	General Electric Company
GI	Grayhill, Incorporated
HBJ	Howard B. Jones Company
HEC	Hoffman Electronics Corp.
H-P	Hewlett-Packard Company
IRC	International Resistance Company
JED	Jeffers Electronics Div., Speer Carbon Co.
LTF	Littlefuse, Incorporated
MOT	Motorola Semiconductor Div., Motorola, Inc.
MSC	Miller, Sanford Co.
PRM	P. R. Mallory & Company
RCA	Radio Corporation of America
SECO	Sangamo Electric Co.
SEP	Sylvania Electric Products, Semiconductor Div.
SI	Switchcraft, Inc.
SPR	Sprague Electric Co.
TEC	Transitron Electronics Corporation
TI	Texas Instruments, Incorporated
TIC	Technology Instrument Corporation
TMC	Tower Mfg. Corporation
W-L	Ward Leonard Electric Company

TABLE OF REPLACEABLE ELECTRICAL PARTS

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
RF UNIT					
AT100		Attenuator Assembly, Variable	308401		
C100	270pf	Capacitor: Fixed, Feedthru, $\pm 10\%$, 500 VDCW	82224	AB	FA5C
C101		Capacitor Assembly, Variable	20116		
C102	20pf	Capacitor: Fixed, Glass, $\pm 5\%$, 500 VDCW	82054	CEC	CYFM10C200J
C103	15pf	Capacitor: Fixed, Feedthru, $\pm 10\%$, 500 VDCW	82051	AB	FA5C
C104	33pf	Capacitor: Fixed, Glass, $\pm 5\%$, 500 VDCW	82163	CEC	CY10C330
C105	75pf	Capacitor: Fixed, $\pm 5\%$, 500 VDCW	82159	SECO	DR1415
C106	220pf	Capacitor: Fixed, Tubular, Ceramic, $\pm 5\%$, 500 VDCW	82222	ERC	GP220-"K"
C107	270pf	Same as C100			
C108	.5-3pf	Capacitor Assembly: Variable Trimmer	300845		
C109		Capacitor Assembly: Variable	300200		
C110	100pf	Capacitor: Fixed, $\pm 5\%$, 500 VDCW	82155	SECO	DR1310
C111, 112	1000pf	Capacitor: Fixed, Feedthru, $\pm 10\%$, 500 VDCW	82307	ERC	370-CB-102K
C113	15pf	Capacitor: Fixed, $\pm 5\%$, 500 VDCW	82057	SECO	DR1415
C114	47pf	Capacitor: Fixed, $\pm 5\%$, 500 VDCW	82158	SECO	DR1447
C115		Capacitor Assembly: Variable	300201		
C116	.5-3pf	Capacitor: Variable	84088	CEC	680079
C117	270pf	Same as C100			
C118	15pf	Same as C103			
C120	250pf	Capacitor: Fixed, Feedthru, $\pm 10\%$, 500 VDCW	82232	ERC	370-CB-251K
C121	1pf	Capacitor: Fixed, $\pm 1/2$ pf, 500 VDCW	82062	C-D	CD15-5V1
C122	.5-3pf	Same as C108			
C123		Capacitor Assembly: Variable	300202		
C124	1 μ f	Capacitor: Fixed, Mylar Film, $\pm 20\%$, 200 VDCW	83142	GA	620M
C126	220pf	Capacitor: Fixed, Feedthru, $\pm 20\%$, 500 VDCW	82204	AB	FA5C
C127-129	15pf	Same as C103			
C130-132	270pf	Same as C100			
C133-135	15pf	Same as C127			
C136-138	10 pf	Capacitor: Fixed, Feedthru, $\pm 10\%$, 500 VDCW	82064	AB	FA5C
C139-141	270pf	Same as C100			
C142	22pf	Capacitor: Fixed, $\pm 5\%$, 500 VDCW	82162	SECO	DR1422
C143	1000pf	Capacitor: Fixed, Standoff, GMV, 500 VDCW	82337	AB	SS5A-102W
C144	1000pf	Capacitor: Fixed, Ceramic Disc, GMV, 600 VDCW	82306	CRL	BB60-102-NZ5Z
C145	1000pf	Same as C111			
C146	15pf	Same as C113			
C147		Special: P/O AT100—not a replaceable part.			
C148	1000pf	Same as C144			
C150	100pf	Capacitor: Fixed, $\pm 10\%$, 500 VDCW	82125	EMC	CM20B101K

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
CR100		Diode, Zener: 43-47V	98028	MOT	IN3695B
CR101		Diode	91093	TEC	S-1029
J100		Connector, BNC	307816	DEC	2230-1
J101		Connector, Receptacle: 6 prong	301754	HBJ	5-306-AB
J102		Connector	89138	DEC	1-310-1
L101, 102	10 μ h	Choke, RF	85593		
L103	5.5 μ h	Choke, RF, (Includes Resistor R126)	85584		
L104		Coil Assembly: 1st Doubler	85582		
L105	14.5 μ h	Choke, RF, (Includes Resistor R128)	85457		
L106		Output Coil Assembly	85583		
L107		Loop, Attenuator	308403		
L108	.16 μ h	Choke Assembly, RF (Includes R115)	85596		
L109-116	50 μ h	Choke, RF	85592		
L117, 118	10 μ h	Choke, RF	85575		
L119, 120	50 μ h	Same as L109			
P101		Connector, Plug: 6 prong	112701	HBJ	P-306-CCT- 63A-AB
P102		Connector	89137	DEC	1-629-1
R100	720 Ω	Resistor: Fixed, $\pm 1/2\%$, 1/2W	80147	CWE	NA15
R101	2.7K Ω	Resistor: Fixed, $\pm 5\%$, 1/8W	80816	TIC	S-18
R102	4.7K Ω	Resistor: Fixed, $\pm 5\%$, 1/4W	80921	AB	CB
R103	100 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80062	AB	EB
R104	12K Ω	Resistor: Fixed, $\pm 5\%$, 1/4W	80920	AB	CB
R105	33K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80461	AB	EB
R106	300 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80779	CEC	C-20
R107	50K Ω	Resistor: Variable, $\pm 10\%$, 2W	81403	AB	JU-5031
R108	18K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80843	AB	HB
R109	8.2K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80859	CEC	C-42
R110, 111	10K Ω	Resistor: Fixed, $\pm 5\%$, 1/4W	80833	AB	CB
R112	1K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80148	AB	EB
R113	12K Ω	Same as R104			
R114	1K Ω	Same as R112			
R115	470 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W, (Part of L108)	85596		
R116	22K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	130203	CEC	C-20
R117, 118	50 Ω	Resistor: Fixed, $\pm 1\%$, 1/8W	80233	DE	DC-1/8
R119	1.5K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80273	AB	EB
R120	10 Meg Ω	Resistor: Fixed, $\pm 10\%$, 1/2W	80682	AB	EB
R121	2.2K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80256	AB	EB
R122	22 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80937	AB	EB
R123, 124	100 Ω	Same as R103			
R125	3.3K Ω	Resistor: Fixed, $\pm 5\%$, 1/4W	132401	AB	CB
R126	10K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W (Part of L103)	85572		
R127	10K Ω	Same as R110			
R128	100K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W (Part of L105)	85457		
R129	100K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80517	AB	EB
R130	100 Ω	Same as R123			
T100		Oscillator Coil Assembly	85581		
V100		Tube, Electron: 6688			
V101		Tube, Electron: 6AF4A			

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SYMBOL CIRCUIT	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
V102, 103		Same as V100			
POWER SUPPLY					
C200	1500 μ f	Capacitor: Fixed, Electrolytic, 50 VDCW	83171	PRM	WP-068
C201A, B	16-16 μ f	Capacitor: Fixed, Electrolytic, 450 VDCW, W/Mtg. Clamp	83170	C-D	BBRD-16D45
C202, 203	8 μ f	Capacitor: Fixed, Electrolytic, 450 VDCW, W/band	83028	AER	PRS-450VDC
C204	.05 μ f	Capacitor: Fixed, Ceramic Disc, +80%—20%, 50 VDCW	83180	C-D	H-05S5
C205	40 μ f	Capacitor: Fixed, Electrolytic, 150 VDCW	83045	AER	PRS-150VDC 40MFD
CR200-203		Rectifier, Silicon: 500 PIV, 1/2A	98006	RCA	INI764
CR204, 205		Rectifier, Silicon: 50 PIV, 3A, W/Mtg. Kit	98019	TEC	INI581
CR206, 207		Rectifier, Silicon: 400 PIV, 1/2A (CR207 not used in all instruments—See CR209.)	91100	RCA	INI763
CR208		Diode, Zener: 7.5-8.2V, 6W	98020	H-P	G-31H-8L
		Diode, Zener: 7.5-8.2V, 6W	98030	H-P	G-31G-8L
CR209		Diode, Zener: 82V, 10W, 10%	98012	MOT	10M82Z10
		Diode, Zener: 91V $\pm$ 10%, 10W (Used as CR209 with CR207 in same instruments)	98027	MOT	IN3004RA
CR210		Diode, Zener: 6.8-7.5V, 90MW	98000	H-P	G-31A-7H
		Diode, Zener: 5-7V, 150 MW	98026	HEC	RT6
CR211		Same as CR206			
CR212, 213		Diode, Zener: 6.8-7.5V, 1.2W	98002	H-P	G-31G-7H
DS200		Lamp, Incandescent: 6.3V, 0.15A, 2 pin base	90910	GE	#12
F200		Fuse: 3A, 115V, 3AG2	93252	LTF	312.003
		Fuse: 1.5A, 230V, 3AG	93250	LTF	31201.5
# F201		Fuse: 3A, 115V, 3AG2	93252	LTF	312.003
		Fuse: 3A, 115V, 3AG, SLO BLO	95032	LTF	313.003
L200	4h	Choke, Filter	85452	FTC	34764
L201	5h	Choke, Filter	85412	FTC	24913
P200		Connector, Receptacle: Male, 3 pin	308087	TMC	H-1061-IG
Q200		Transistor	98502	BC	2N1136
Q201		Transistor	98505	MOT	2N1533
Q202-204		Transistor	98504	TI	2N1379
R200	400 Ω	Resistor: Fixed, WW, $\pm$ 10%, 10W	80806	W-L	10F
R201	600 Ω	Resistor: Variable, WW, $\pm$ 10%, 10W	81134	W-L	10A
R203	13K Ω	Resistor: Fixed, $\pm$ 5%, 2W	80916	AB	HB
R204	12K Ω	Resistor: Fixed, $\pm$ 5%, 2W	80868	AB	HB
R205	30 Ω	Resistor: Fixed, $\pm$ 5%, 2W	80815	CEC	C-42
R206	15K Ω	Resistor: Fixed, $\pm$ 3%, 3W	80813	DE	RS-2B
† R207	3K Ω	Resistor: Variable, $\pm$ 10%, 1/2W	81136	IRC	RQL11-112
	400 Ω	Resistor: Variable, $\pm$ 5%, 2W	81142	CMC	43C2-400
† R208	14K Ω	Resistor: Fixed, $\pm$ 3%, 3W	80811	DE	RS-2B
	15K Ω	Resistor: Fixed, $\pm$ 3%, 3W	80813	DE	RS-2B
† R209	750 Ω	Resistor: Fixed, WW, $\pm$ 3%, 3W	80869	DE	RS-2B
	470 Ω	Resistor: Fixed, WW, $\pm$ 3%, 3W	134951	DE	RS-2B
R210, 211	470 Ω	Resistor: Fixed, Comp., $\pm$ 5%, 1/2W	80168	AB	EB
R212	75K Ω	Resistor: Fixed, Comp., $\pm$ 5%, 2W	80510	AB	EB

Use fuse indicated on rear panel of instrument.

† See Fig. 69, Schematic Revisions.

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
R213	15K Ω	Resistor: Fixed, Comp., $\pm 5\%$, 1/2W	80336	AB	EB
R214	15K Ω	Same as R206			
R215, 216	51 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80088	AB	EB
R217	18K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80843	AB	HB
S200		Switch, Toggle	88059	AH	81027CE
S201		Switch, Snap Slide	88003	H-P	3101-0033
T200		Transformer, Power	85087		
W200		Power Cord Assembly	308086		
AGC AMPLIFIER					
C300	100pf	Same as C150			
C301	.47 μ f	Capacitor: Fixed, $\pm 5\%$, 100 VDCW	83179	GA	663F
† C302	25 μ f	Capacitor: Fixed, 50 VDCW	83166	AER	PTT95
† C303	25 μ f	Capacitor: Fixed, 50 VDCW	83166	AGR	PTT95
† CR300		Diode, Zener: 6.8-7.5V, 90MW	98000	H-P	G-31A-7H
† CR301, 302		Diode, Zener: 11-12V, 90MW	98017	H-P	G-31A-12L
† CR303		Diode, Zener: 6.8-7.5V, 1.2W	98002	H-P	G-31G-7H
† CR304		Diode, Zener: 24V, $\pm 10\%$, 3/4W	98029	MOT	IN3688A
L300	1mh	Choke	85456		
M300		Meter, RF Monitor	92050-1		
R300	20K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81326	CTS	Type 70
R301	560K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80629	AB	EB
R302	1K Ω	Resistor: Variable, $\pm 10\%$, 2W	81225	AB	Type J
† R303	150K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80527	AB	EB
	220K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80555	AB	EB
† R304	1K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80148	AB	EB
	3.3K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80253	AB	EB
R305	220K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80555	AB	EB
R306	470K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80640	AB	EB
R307	10K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80747	CEC	C-42
† R308	500K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81621	CTS	Type 70
	200K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81519	CTS	Type 70
† R309	68K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80549	AB	EB
R310	390 Ω	Resistor: Fixed, $\pm 5\%$, 1W	80879	CEC	C-32
R311	2K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81214	CTS	Type 70
† R312	220 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80188	AB	EB
	6.8K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80387	AB	EB
R313	500K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81621	CTS	Type 70
R314	220K Ω	Same as R303			
R315	33K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80461	AB	EB
	24K Ω	Resistor: Fixed, $\pm 5\%$, 1W	80464	AB	GB
R316	3.3K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	130202	CEC	C-20
R317	1.5K Ω	Same as R119			
R318	56K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80556	AB	EB
R319	7.5K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80412	AB	EB

V300A, B Tube, Electron: 6AW8A

† See Fig. 67, Schematic Revisions.

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CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
FM CATHODE FOLLOWER					
C400	.001 μ f	Same as C144			
C401	.1 μ f	Capacitor: Fixed, Mylar Film, $\pm 20\%$, 400 VDCW	82456	GA	620M
C402	.47 μ f	Same as C301			
J400, 401		Binding Post: Red	304312	GI	29-1R
J402		Jack, Phone: Open Circuit	89038	SI	#1R
J403		Binding Post: Black	304311	GI	29-IB
L400	50 μ h	Choke	85592		
R405	180 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80222	AB	EB
R406	4.7K Ω	Resistor: Fixed, $\pm 5\%$, 1W	80305	AB	GB
R407	470K Ω	Same as R306			
R408	100K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W	80919	TI	CD1/2PR
R410	1K Ω	Resistor: Variable, $\pm 5\%$, 2W	81132	BI	SG-832
R411	1MEG Ω	Resistor: Fixed, $\pm 1\%$, 1/2W	80799	TI	CD1/2PR
R412	2MEG Ω	Resistor: Fixed, $\pm 1\%$, 1/2W	80972	TI	CD1/2PR
R413	22K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80472	AB	EB
R414	15K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W	80909	TI	CD1/2PR
R415	15.8K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80821	TI	CD1/2PR
R416	7.5K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W	80910	TI	CD1/2PR
R417	1K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80826	TI	CD1/2PR
R418	100 Ω	Same as R123			
R419	200K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81519	CTS	Type 70
V400B		Tube, Electron: 6BK7B (V400A not used)			
AUDIO OSCILLATOR AND AMPLIFIER (DUAL)					
C500	.01 μ f	Capacitor: Fixed, $\pm 1\%$, 500 VDCW	82454	C-D	1DR5S1
C501	1000pf	Capacitor: Fixed, $\pm 1\%$, 500 VDCW,	82340	C-D	5R501
C502	.01 μ f	Same as C500			
C503	985pf	Capacitor: Fixed, $\pm 1\%$, 500 VDCW, Silver Mica	82341	C-D	5R5T985R
C504	.01 μ f	Capacitor: Fixed, GMV, 450 VDCW	82428	CRL	DAO48-003A
C505	.5 μ f	Capacitor: Fixed, Mylar Film, $\pm 10\%$, 200 VDCW	83161	GA	620M
C510	.1 μ f	Same as C401			
C511A, B	20-20 μ f	Capacitor: Fixed, Electrolytic, 450 VDCW	83051	C-D	UP2245
C512	8 μ f	Same as C202			
C513	.5 μ f	Capacitor: Fixed, $\pm 10\%$, 400 VDCW	83161	GA	620M
	.01 μ f	Capacitor: Fixed, GMV, 450 VDCW	82428	CRL	DAO48-003A
C514	40 μ f	Capacitor: Fixed, Electrolytic, 350 VDCW, W/Mtg. Clamp	83164	C-D	BR4035
	8 μ f	Capacitor: Fixed, Electrolytic, 450 VDCW, NON-POLARIZED	148152	AER	PRSNP450 VDCW 8 MFD
C516	60 μ f	Capacitor: Fixed, Electrolytic, 300 VDCW, with insulating cover.	83100	SPR	TVL-1570
I500		See RT 500			
J500		Jack: Closed Circuit	89039	SI	12A
R500, 501	332K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80785	TI	CD1/2PR
	334K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	131509	TI	CD1/2PR

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
R502, 503	40.2K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80786	TI	CD1/2PR
R504, 505	15.8K Ω	Same as R415			
R506, 507	5.23K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80917	TI	CD1/2PR
R508, 509	21K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80822	TI	CD1/2PR
R510	10K Ω	Resistor: Variable, $\pm 10\%$, 2W	81314	AB	JLU-1031
R511	150K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80527	AB	EB
R512	470K Ω	Same as R306			
R513	220K Ω	Same as R305			
R514	6.8K Ω	Resistor: Fixed, $\pm 10\%$, 4W, Metal Film	80790	CEC	LP1-4
	5.6K Ω	Resistor: Fixed, $\pm 10\%$, 4W, Metal Film	130902	CEC	LP1-4
R515	510 Ω	Resistor: Fixed, $\pm 5\%$, 1W	80128	AB	EB
R516	6.8K Ω	Resistor: Fixed, $\pm 5\%$, 1W	80322	AB	GB
R517	100K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80517	AB	EB
	220K Ω	Same as R303			
R518	7.5K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80857	CEC	C-42
	1.2K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80201	AB	EB
R519	7.5K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80857	CEC	C-42
	22K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80472	AB	EB
R520	10K Ω	Resistor: Variable, $\pm 10\%$, 2W	81340	AB	Type J
R521	47K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80460	AB	EB
R522	100 Ω	Same as R103			
R523, 524	10.5K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80918	TI	CD1/2PR
R525, 526	6.34K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80865	TI	CD1/2PR
R527	680 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80138	AB	EB
R528	100K Ω	Same as R129			
R529	4.7K Ω	Resistor: Fixed, $\pm 5\%$, 4W, Metal Film	103901	CEC	LP1-4
R530	1Meg Ω	Resistor: Fixed, $\pm 5\%$, 1W	80621	AB	EB
R531	220K Ω	Same as R303			
R532	22K Ω	Resistor: Fixed, $\pm 5\%$, 1W	80404	AB	GB
R533	33K Ω	Same as R105			
R534	150 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80098	AB	EB
R535	100 Ω	Same as R418			
R536	1K Ω	Same as R112			
RT500		Lamp, Incandescent: 120V, 3W	90907	GE	3S6/5
S500		Switch, Rotary: FREQ CPS	88058		
V500		Tube, Electron: 6AU6A			
V501		Tube, Electron: 6AQ5A			
V502		Tube, Electron: 12AU7A			
		Tube, Electron: 6AW8A			
MODULATION METER CIRCUIT					
C600	.5 μ f	Same as C505			
C601	100 μ f	Capacitor: Fixed, Electrolytic, 6 VDCW	83133	C-D	PTT30 PWE6100
C602, 603	.1 μ f	Same as C401			
C604	470pf	Capacitor: Fixed, $\pm 5\%$, 500 VDCW	146651	AEI	DM-19-471J
C605	16 μ f	Capacitor: Fixed, Electrolytic	83136	C-D	BBR-16-150
C606	1000pf	Same as C400			
C607	10 μ f	Capacitor: Fixed, Electrolytic, 25 VDCW	83181	AER	PTT79
C609	30pf	Capacitor: Fixed, $\pm 2\%$, 600 VDCW	82048	ERC	NPOCC25, CH300G

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CR601, 602		Diode, Silicon: 120V PIV	98022	TI	IN660
M600		Meter, Modulation	92051-2		
R600	120K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80550	AB	EB
R601	390 Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80182	AB	EB
R602	18K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80381	AB	EB
R603	1.8K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80234	AB	EB
R604	390K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80611	AB	EB
R605	390 Ω	Same as R601			
R606	15K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80336	AB	EB
R607	1.8K Ω	Same as R603			
R608	390K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80611	AB	EB
	1.2Meg Ω	Resistor: Fixed, $\pm 5\%$, 1/2W	80646	AB	EB
R609	100 Ω	Same as R418			
R610	3.9K Ω	Resistor: Fixed, $\pm 5\%$, 2W	80912	CEC	C-42
R611	150 Ω	Resistor: Fixed, $\pm 5\%$, 1W	80878	CEC	C-32
R612	100K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81517	CTS	Type 70
R613, 614	10.5K Ω	Same as R523			
R615	100 Ω	Same as R418			
R616	21K Ω	Same as R508			
R618	100 Ω	Same as R418			
R619	1K Ω	Same as R417			
R620	56K Ω	Resistor: Fixed, $\pm 5\%$, 1/2W, Metal Film	80804	CEC	C-20
R621	220K Ω	Same as R513			
V600, 601		Tube, Electron: 6AU6A			
V602		Tube, Electron: 6DJ8			

SWITCHING

C702	.5 μ f	Capacitor: Fixed, $\pm 10\%$, 200 VDCW, Mylar Film	83161	GA	620M
	1 μ f	Same as C124			
R702	5K Ω	Resistor: Variable, $\pm 10\%$, 2W	81318	AB	Type J
R703	4.02K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80792	TI	CD1/2PR
R704	2.8K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80824	TI	CD1/2PR
R705	800 Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80793	TI	CD1/2PR
R706	280 Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80825	TI	CD1/2PR
R707	120 Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80798	TI	CD1/2PR
R709	2K Ω	Resistor: Fixed, $\pm 1\%$, 1/2W, Carbon Film	80911	TI	CD1/2PR
R721	50K Ω	Resistor: Variable, $\pm 30\%$, 0.2W	81516	CTS	Type 70
R726	15K Ω	Same as R606			
S700A-C		Switch, Rotary: INT MOD	307949		
S701		Switch, Rotary: DEV KC	307951		
S702A, B		Switch, Rotary: MOD METER	88060		
S703A-D		Switch, Rotary: RF RANGE	307790		

TABLE OF REPLACEABLE MECHANICAL PARTS

BRC PART NO.	DESCRIPTION	QTY. PER UNIT
20112	Deviation Rotor Assembly	1
20115	Bracket, Main Drive Shaft	1
20116	Stator, Variable Capacitor	1
20241	Rotor Wiper Spring Assembly	4
20248	Can, Shield	1
20272	RF Shielding Braid	1
20276	Stator Mount	3

70097	Collar	1
84048	Plate, Stop	1
84059	Rotor	1
84061	Stator, Variable Capacitor	1
84062	Stator, Variable Capacitor	1
84063	Stator, Variable Capacitor	1
88826	Shield, Electron Tube (V400, V502, V602)	3
89075	Shield, Electron Tube (V101)	1
89088	Shield, Electron Tube (V500, V600, V601)	3
89099	Socket, Electron Tube (V100, V102, V103)	3
89113	Socket, Lamp: RT 500	1
89139	Socket, Electron Tube (V500, V501, V600, V601)	4
89140	Socket, Electron Tube (V300, V400, V502, V602)	4
89142	Lamp Holder Assembly: DS200	1
90064-5	Terminal Strip Assembly	2
90064-7	Terminal Strip Assembly	1
90064-8	Terminal Strip Assembly	2
93149	Ball, Pyrex Glass	2
93155	Bearing, Thrust	1
94231	Gear	1
98002	Clip, Mounting: Q202	1
98800	Transistor Mount — (Q200, Q201) — Used on Instruments Serial Numbered 5928 and below.	2
98803	Clip, Mounting: Double, Q203, Q204	1
98804	Transistor Socket — (Q200, Q201) — Used on Instruments Serial Numbered 5928 and above.	2
107801	Washer, Flat	1
211521	Clamp, Dial Lock	1
211576	Washer, Spring	1
300029	Spacer, Shaft	1
300065	Washer, Flat	6
300080	Washer, Spring	4
300081	Ring, Retaining	
300085-2	Stop Collar Assembly	1
300162	Socket, Electron Tube: V101	1
300200	Stator and Mount Assembly	1
300201	Stator and Mount Assembly	1
300202	Stator and Mount Assembly	1
300203	Rotor Assembly	1
300331	Terminal, Insulated	19
300856	Terminal, Insulated	4
301055	Spring, Helical Extension	2
301684	Shield, Electron Tube: (V300)	1
301944	Gear	1
302324	Gear and Pin Assembly	1
302652-3	Shield, Electron Tube: (V100, V102)	2
302652-5	Shield, Electron Tube: (V501)	1
303179	Ring, Retaining	1
303222	Gasket, Shielding	1
303375	Washer, Flat	1
304217	Clamp, Loop: Burndy HP-7N	4
304467	Clamp, Loop: Burndy HP-5N	3
304469	Clamp, Loop: Burndy HP-4N	1
304501	Clamp, Loop: Burndy HP-9N	2
304505	Clamp, Loop: Burndy HP-6N	1
305149	Cable	1

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306511	Fuseholder Post	2
306577	Knob	4
306579	Knob	1
306579-1	Knob	1
306588	Knob	2
306616	Knob	4
307662	Spacer, Sleeve	2
307671	Stud, Shield Can Retainer	3
307675	Washer, Flat	5
307690	Dial Assembly, Frequency	1
307700	Terminal Board	1
307708	Dial Assembly, Attenuator	1
307777	Bellows, Coupling Shaft	2
307784	Dial Assembly, Vernier	1
307785	Guide, Fiducial	4
307786	Mask, Fiducial	1
307788	Cam and Hub Assembly	1
307789	Guide, Fiducial	1
307790	Wafer, Range Switch	1
307791	Fiducial, Attenuator	1
307792-2	Gear Box Subassembly	1
307805	Gear, Spur	1
307806	Fiducial, Δ F KC and VERNIER	2
307808	Gear, Spur	1
307809	Shaft, Range	1
307817	Holder, Shock Mount	4
307818	Snubbing Washer: Flat	8
307819	Snubbing Collar: Rubber	4
307828	Shaft, Range Switch	1
307838	Spacer, Shaft	1
307862	Insulator, Transistor: Q201	2
307881	Washer, Flat: Phenolic	4
307921	Spacer: Threaded, Hex	4
307922	Spacer: Threaded, Hex	2
307923	Spacer, Threaded Hex	2
307931-2	Rear Plate Assembly	1
307934	Tube & Support Assembly	1
307935	Shaft, Attenuator	1
307937	Washer, Flat	1
307977	Block, Mounting	1
307978	Collar, Clamp	1
307982	Bushing, Shaft	1
307990	Dial Assembly, Δ F KC	1
307995	Collar & Pin Assembly	1
307998	Shaft and Detent	1
308000	Shaft Assembly, Frequency	1
308124	Foot Assembly	5
308132	Side Handle Assembly	2
308136	Strip, Large Filler	1
308137-51	Strip, Trim (Adhesive Backed)	2
308155	Nut, Clip: Tinnerman	8
308348	Terminal Board	1
308534	Terminal Board	1
308539	Bearing, Plate	1
308547	Clamp, Loop: Tinnerman C2980-9-A27 (C124)	1
308589	Terminal Strip	1
308592	Terminal Strip	1

308645	RF Filter Assembly	1
308646	Bushing, Dial Lock	1
308648	Cam Shaft Assembly (Includes gear)	1
308649	Gear	1

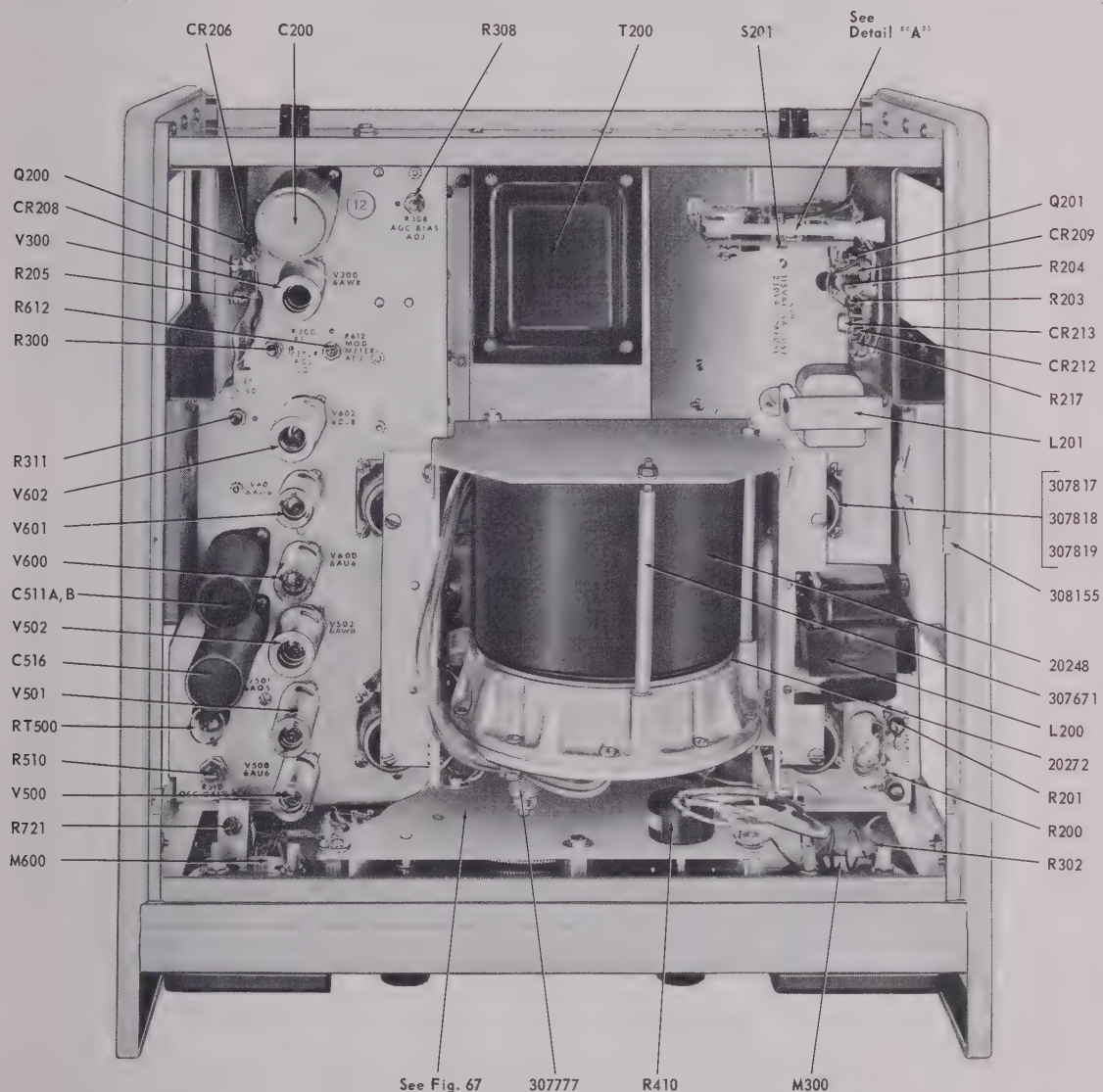
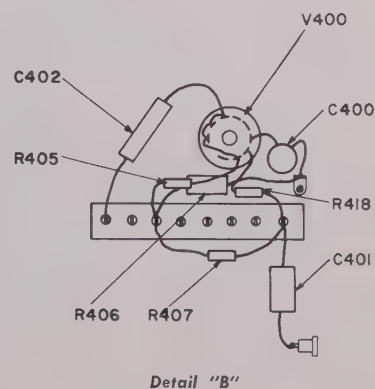
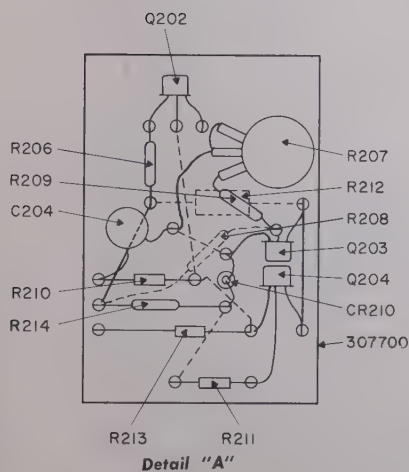


Figure 58.202H — Top View



Detail "B"

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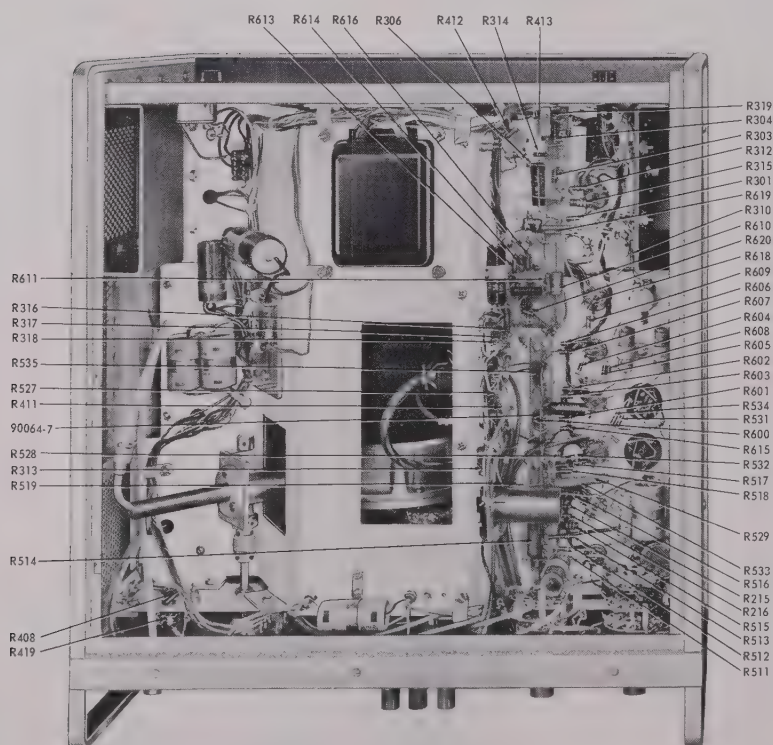
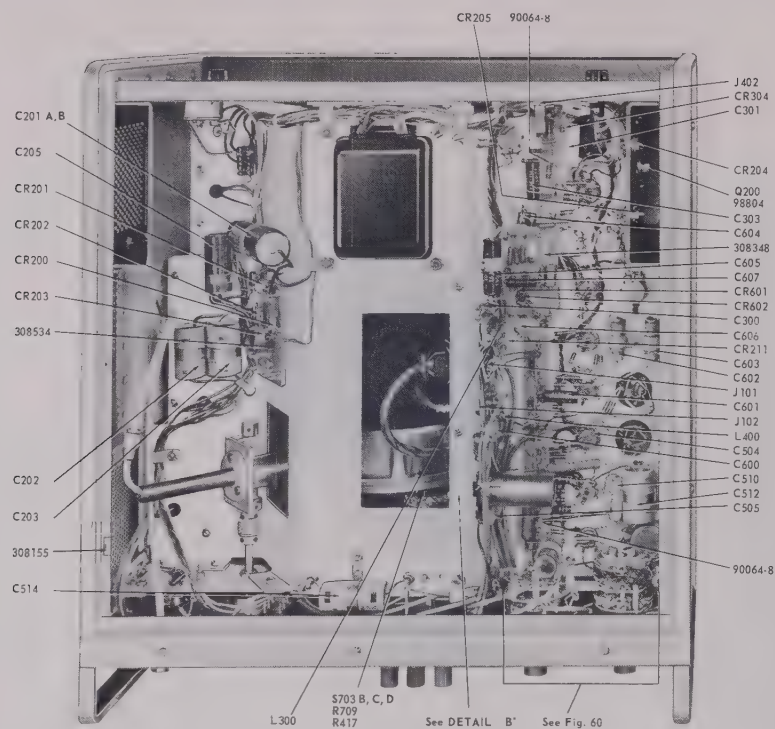


Figure 59. 202H — Bottom View

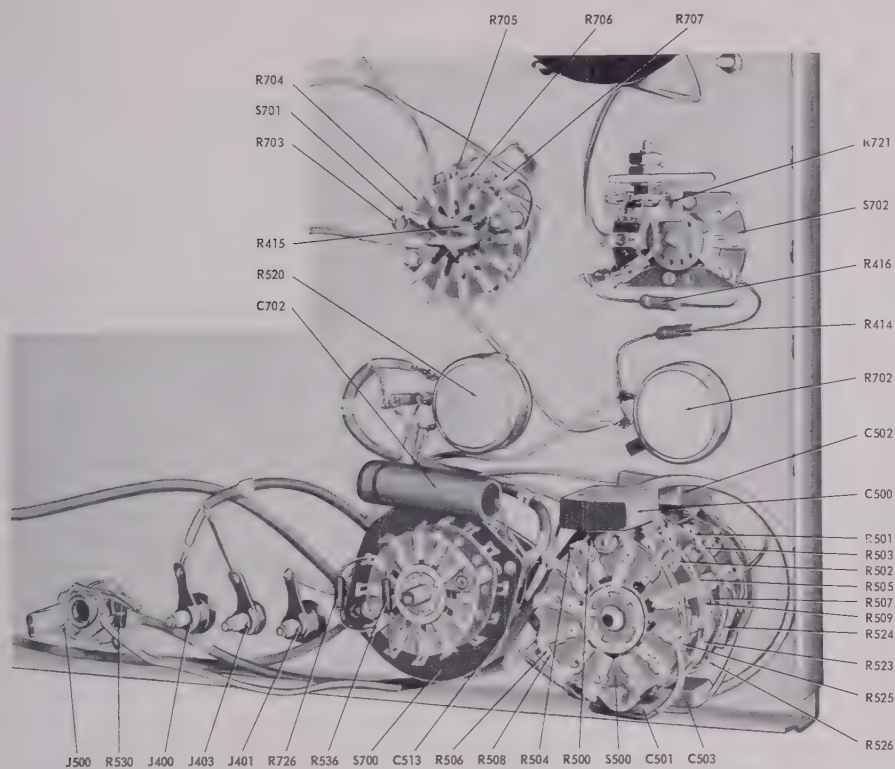


Figure 60. 202H Front Panel — Rear View

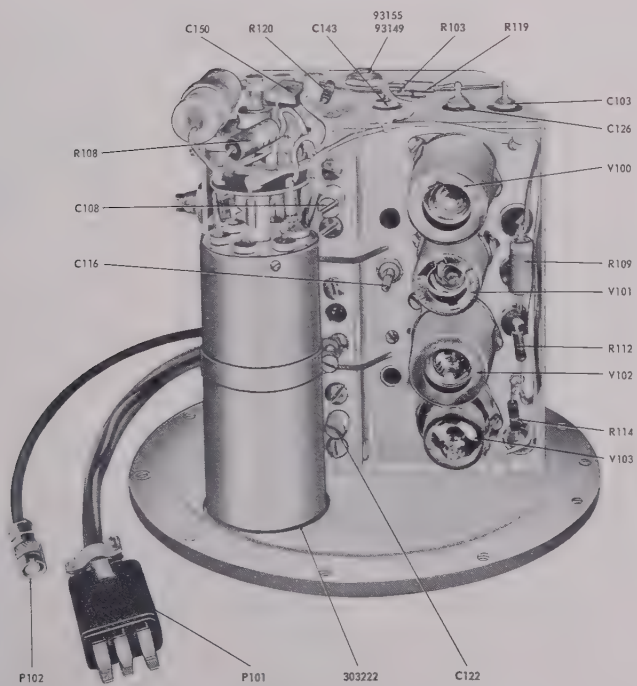


Figure 61. RF Unit — Top View

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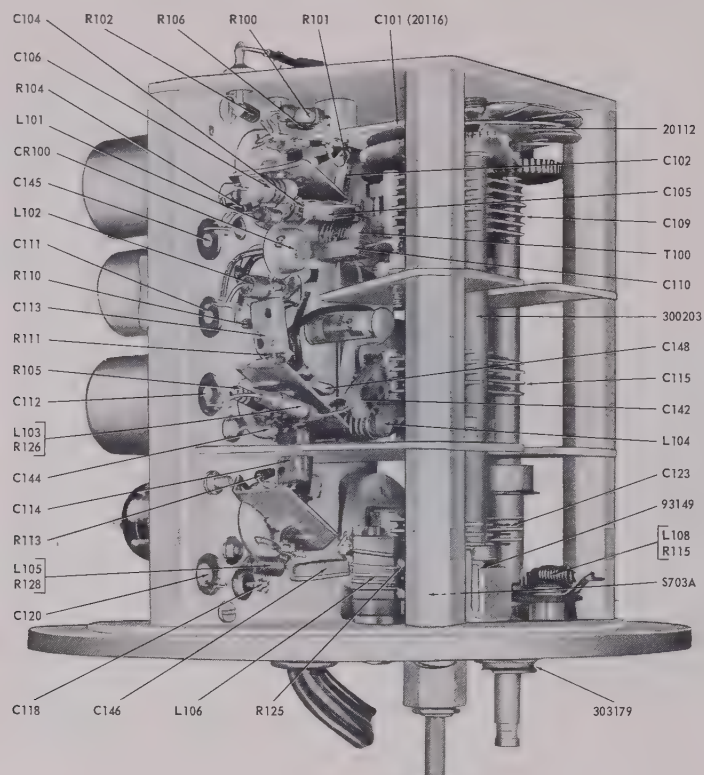


Figure 62. RF Unit — Bottom View

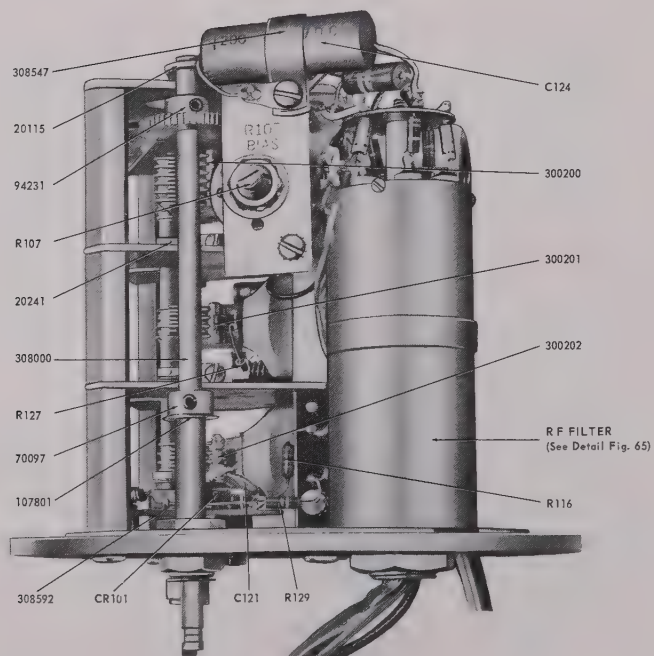


Figure 63. RF Unit — Side View

Diagram illustrating the components of a spray gun assembly, labeled with part numbers:

- 307995
- 301055
- 840 48
- 307935
- 300085-2
- 300065
- 301944
- 302324
- 307934
- 300080
- 300029
- 305149
- J100
- R118
- C147
- R117
- L107

55

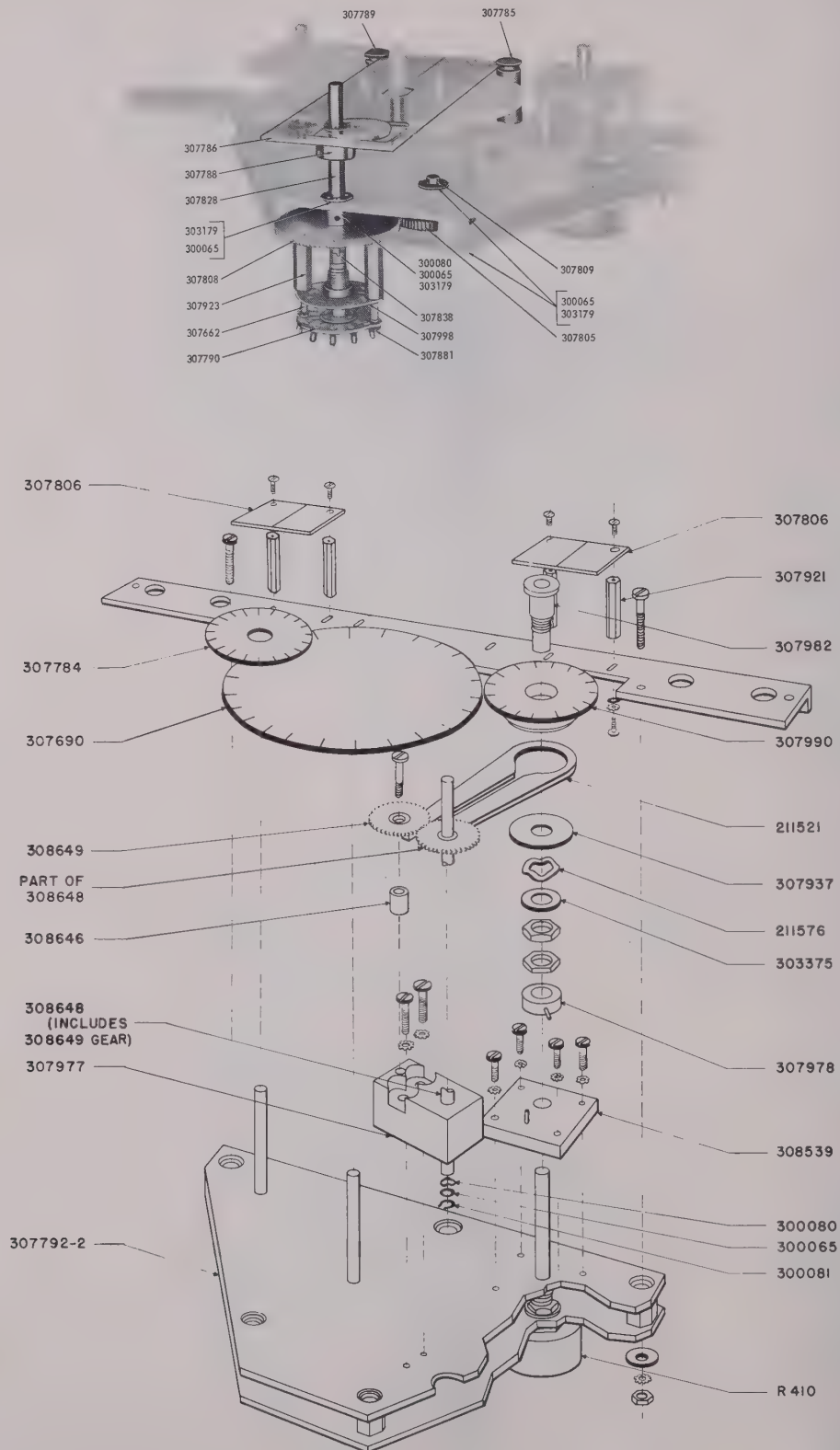


Figure 67. Gear Box Assembly

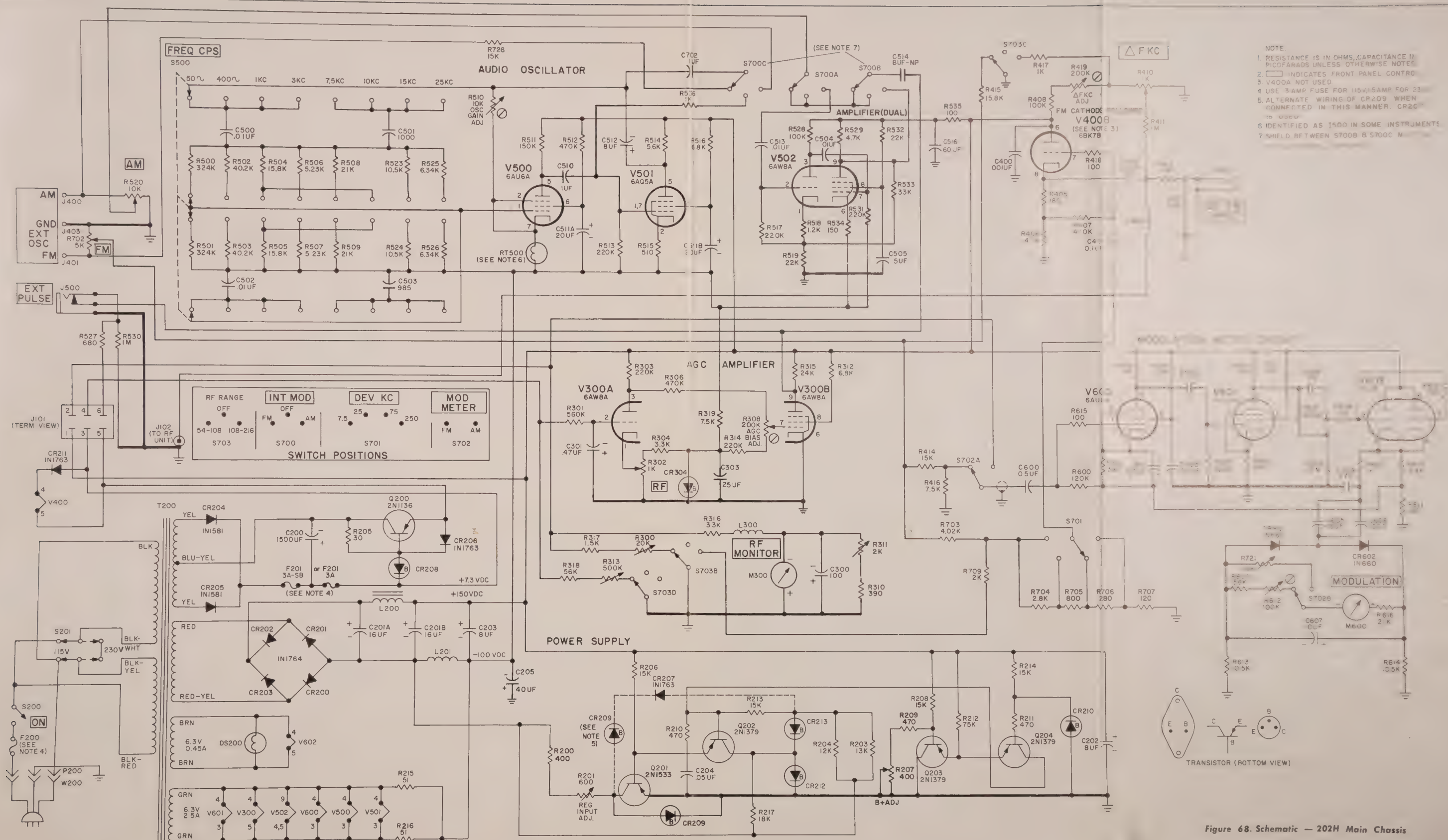
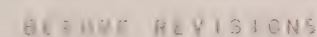


Figure 68. Schematic — 202H Main Chassis
(See Fig. 69 on Page 58 for Schematic Revisions)



Changes in other Circuits (Not shown on revision schematics)

Figure 69 Schematic — 202H Revisions

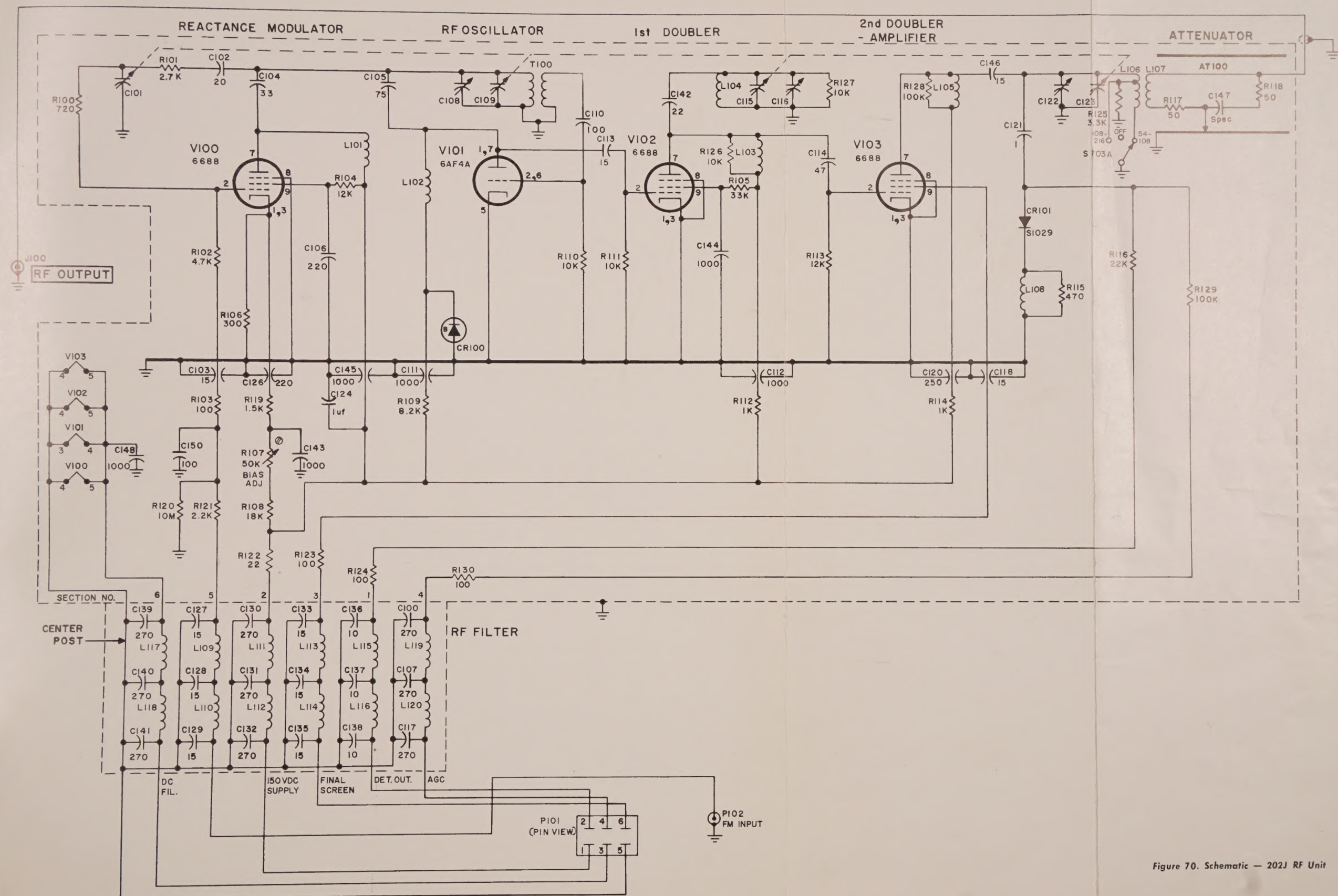


Figure 70. Schematic — 202J RF Unit

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